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Hydraulic Research in the United States and Canada, 1972

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Hydraulic Research in the United States and Canada, 1972

Edited by

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ABSTRACT

Current and recently concluded research projects in hydraulics and hydrodynamics for the years 1971-1972 are summarized. Projects from more than 250 university, industrial, state and federal government laboratories in the United States and Canada are reported.

Key words: Fluid mechanics; hydraulic engineering; hydraulic research; hydraulics; hydrodynamics; model studies; research summaries.

PREFACE

This publication first appeared in 1933 as "Hydraulic Research in the United States" in answer to a need to keep hydraulicians aware of pertinent current activity in research laboratories throughout the United States and Canada. With the exception of a few World War II years, it was published annually through 1966, after which publication became biennial. With this 1972 issue it appears for the first time with the title "Hydraulic Research in the United States and Canada."

The National Bureau of Standards appreciates the cooperation of the more than 250 organizations which have contributed to this issue their summaries of hydraulic and hydrologic research and of other fluid mechanics research of interest and usefulness to hydraulicians. These reporting organizations are listed beginning on page vi. Although efforts are made to solicit reports from all laboratories whose work comes to our attention, the National Bureau of Standards cannot assume responsibility for the completeness of this publication. We must depend in the last analysis upon reporting laboratories for the completeness of the coverage of their own programs, and upon new laboratories engaged in pertinent research to bring their activities to our attention.

Detailed information regarding the research projects reported here should be obtained from the correspondent listed under (c) or immediately following the title and address of the organization reporting the work. The National Bureau of Standards does not maintain a file of publications, reports or other detailed information on research projects reported by other laboratories. It is of course understood that laboratories submitting reports on their work will be willing to supply additional information to properly qualified inquirers.

Readers of "Hydraulic Research in the United States and Canada" can find related information in the "Water Resources Research Catalog," prepared by the Science Information Exchange of the Smithsonian Institution for the Office of Water Resources Research, U. S. Department of the Interior. Information on that publication can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. (See also Key to Projects on next page.)

ACKNOWLEDGEMENT

The Office of the Chief of Engineers, U. S. Army, contributed partial financial support to the preparation of the 1972 issue of "Hydraulic Research in the United States and Canada."

CONTENTS

KEY TO PROJECTS

The project summaries are grouped in three sections: (1) U. S. university, state and industrial laboratories, (2) U. S. Government laboratories, and (3) Canadian laboratories. Within each section the source laboratories are listed alphabetically (see List of Contributing Laboratories on page vi) and are numbered sequentially using the first three digits of the identification number.

(a) Project number and title

In the thirteen-digit identification number, e.g., 129-01111-000-00, preceding each title, the second (five-digit) group, e.g., 01111, is the project number. Once assigned, this number is repeated in each issue for identification purposes until the project is completed. In this issue the numbers 07832 and above are projects being reported for the first time. Projects with lower numbers can be found in earlier issues with the zero deleted, e.g. (1111). Numbers followed by W, e.g. 0122W, identify projects which are included here by title only and are completely summarized in "Water Resources Research Catalog." See Preface.

(b) Project conducted for

Only out-of-house sponsors are listed here. Absence of an entry indicates in-house support. (See also Supporting Agency Index.)

(c) Correspondent

Where there is no entry here, refer to the correspondent cited directly following the title and address of the reporting laboratory.

(d) Nature of Project

Basic or applied; theoretical, experimental; thesis, etc.

(e) Description of Project

(f) Present status

Absence of an entry here implies that the project was in an active status at time of submission.

(g) Results

In many continuing projects this section contains only results since the previous issue of "Hydraulic Research in the United States." For completeness, readers are encouraged to consult earlier issues and/or publications listed under (h).

(h) Publications

For the continuing projects, only publications since the last issue are generally listed. Older publications are listed when there have been no new publications since the last issue or when a project is being reported for the first time. For completeness, readers are encouraged to consult earlier issues.

LIST OF CONTRIBUTING LABORATORIES

U. S. UNIVERSITY, STATE AND INDUSTRIAL LABORATORIES Page

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U. S. GOVERNMENT AGENCIES

- - - - - - - - - -

CANADIAN LABORATORIES

- - - - - - - - - - -

PROJECT REPORTS FROM UNIVERSITY, STATE, AND INDUSTRIAL LABORATORIES

ACRES AMERICAN INCORPORATED LABORATORY, 455 Cayuga Road, Buffalo, N.Y. 14225. J. A. Tallis, Ph.D., Chief Hydraulic Engineer. (See also Acres Consulting Services Limited, Canada.)

001-08156-340-75

NINE MILE POINT THERMAL MODEL

(*b*) Quirk Lawler and Matuski Engineers, 415, Route 303, Tappan, N.Y. 10983.
(*d*) Experimental; design.
(*e*) An existing nuclear unit is located at Nine Mile Point on the Lake Ontario Shoreline. The Niagara Mohawk Power Corporation is planning an additional nuclear unit at the same site. A 1:80 natural scale model is being utilized for the investigation of the combined thermal discharge from both of these units. The model covers a lake area of approximately 4 miles by 3 miles and also includes simulation of the discharge from P.A.S.N.Y. Fitzpatrick plant which is currently under construction approximately 1 mile to the east. A system of adjustable weirs enables lake drift currents both eastwards and westwards to be simulated so that effects of the combined heat inputs by the two stations can be studied. Model temperatures will be measured by the use of almost 300 temperature sensors and the information retrieved through an automatic system which includes a mini-computer for preliminary processing of the data. The object of the study is to optimize the design configuration of the combined Nine Mile Point discharge structure and to demonstrate to regulatory agencies such as the Atomic Energy Commission, the N.Y. State Department of Environment Conservation and the U.S. Corps of Engineers that compliance with water quality standards is met.

AEROSPACE CORPORATION, P.O. Box 95085, Los Angeles, Calif. 90045. Dr. A. Mager, Vice President and General Manager, Engineering Science Operations.

003-07917-090-00

STUDIES OF SWIRLING FLOWS

(*d*) Theoretical; applied research.
(*e*) Investigation of free and confined swirling flows with particular emphasis on the breakdown phenomena.
(*h*) **Incompressible, Viscous, Swirling Flow Through a Nozzle,** A. Mager, *AIAA J.* **9**, 4, 1971.
Solution Across Vortex Breakdown, A. Mager, Aerospace Corp., *ATR-71(9999)-1*, 26 Apr. 1971.

UNIVERSITY OF AKRON, Department of Chemical Engineering, Akron, Ohio 44304. Department Head.

004-07918-270-40

BIOMEDICAL IMPLICATIONS OF DRAG REDUCING AGENTS

(*b*) National Heart and Lung Institute.
(*c*) Drs. H. L. Greene, R. F. Nokes, L. C. Thomas, c/o Institute for Science and Engineering Research.
(*d*) Experimental, theoretical, and encompasses both basic and applied research.
(*e*) Research is being undertaken to determine both hydrodynamic and biological effects of soluble polymeric substances (drag reducing agents) on blood flow. Existence of turbulence within the vascular system suggests that more efficient pumping of blood may be possible when minute quantities of these agents are added.
(*g*) Results have shown that pressure drop in turbulent blood flow (*in vitro*) is substantially reduced by polymer addition. *In vivo* experiments will hopefully substantiate this. Toxicity of typical drag reducing polymer appears minimal. Turbulence intensity and renewal frequencies as obtained by hot-film anemometer data have been found to be substantially decreased. Other effects of fluid viscoelasticity on vascular flows are also being investigated.

ARIZONA STATE UNIVERSITY, Department of Mechanical Engineering, Tempe, Ariz. 85281. Professor Warren Rice, Department Chairman.

005-06051-210-00

UNSTEADY LAMINAR FLOW FIELD ANALYSIS

(*d*) Analytical; applied research; Doctoral thesis.
(*e*) Development of methods of solving unsteady laminar flow problem in complex conduits.
(*f*) Completed.
(*g*) Solutions for the laminar flow of an incompressible fluid in a conduit of arbitrary cross-section, from an arbitrary initial flow condition and with an arbitrary time-varying pressure gradient.
(*h*) **Laminar Flow of an Incompressible Fluid in a Conduit with Arbitrary Cross-Section, Arbitrary Time-Varying Pressure Gradient, and Arbitrary Initial Velocity,** H. K. Hepworth, Warren Rice, *J. Basic Engrg., ASME Trans.*, Paper No. 71-WA/FE-22.
Laminar Two-Dimensional Flow in Conduits with Arbitrary Time-Varying Pressure Gradient, H. K. Hepworth, Warren Rice, *J. Appl. Mech., ASME Trans.* **37**, Ser. E, 3, pp. 861-864, Sept. 1970.

005-07141-000-00

LAMINAR FLOW BETWEEN CO-ROTATING DISKS

(*d*) Analytical and experimental; applied research; Doctoral and MSE theses.
(*e*) Development of solutions for flow useful in development and design of multiple-disk turbomachinery; experimental investigation of criteria for transition of laminar to turbulent flow, and experimental confirmation of analytical descriptions earlier obtained.
(*g*) Production of design maps for multiple-disk turbomachinery; data obtained experimentally for determining criteria for transition from laminar to turbulent flow between co-rotating disks; experimental determination of streamlines for wide range of operational parameters for such flows.
(*h*) **Integral Method for Flow Between Co-Rotating Disks,** B. E. Boyack, Warren Rice, *J. Basic Engrg., ASME Trans.* **93**, Series D, 3, pp. 350-354, Sept. 1971.

Experimental Investigation of the Flow Between Co-Rotating Disks, R. G. Adams, Warren Rice, *J. Appl. Mech., ASME Trans.* **37**, Series E, 3, pp. 844-849, Sept. 1970.

An Integral Solution for the Laminar Radial Outflow of a Viscous Fluid Between Parallel Stationary Disks, B. E. Boyack, Warren Rice, *J. Basic Engrg., ASME Trans.* **92**, Series D, 3, pp. 662-663, Sept. 1970.

Laminar Throughflow of Newtonian Fluid Between Co-Axial Rotating Cones, K. W. McAlister, Warren Rice, *J. Appl. Mech., ASME Trans.* **37**, Series E, 1, pp. 210-212, Mar. 1970.

A Composite Solution Method for Analytical Design and Optimization Studies of a Multiple-Disk Pump, M. E. Crawford, *MSE Thesis*, Mech. Engrg., Arizona State Univ., Feb. 1972.

An Investigation of Multiple-Disk Turbine Performance Parameters, M. J. Lawn, Jr., *MSE Thesis*, Mech. Engrg., Arizona State Univ., Jan. 1972.

005-07142-000-00

LAMINAR FLOW BETWEEN ROTATING SURFACES OF REVOLUTION

(*d*) Analytical; basic and applied research for Doctoral thesis and experimental investigations for MSE theses.
(*e*) Development of solutions for the velocity and pressure fields for flow of a hydraulic fluid between surfaces of revolution that are rotating or stationary; experimental confirmation of mathematical model and calculation methods.
(*g*) Similarity solutions for several families of surface shapes, both rotating and stationary, with computer programs for solving the similarity problems.
(*h*) **Throughflow Between Rotating Surfaces of Revolution, Having Similarity Solutions,** K. W. McAlister, Warren Rice, *J. Appl. Mech., ASME Trans.* **37**, Series E, 4, pp. 924-930, Dec. 1970.
Flows Between Stationary Surfaces of Revolution, Having Similarity Solutions, K. W. McAlister, Warren Rice, *J. Appl. Mech., ASME Trans.*, Paper No. 72-APM-4.

005-07919-610-20

NOISE REDUCTION IN HYDRAULIC SYSTEMS

(*b*) ONR, Department of the Navy.
(*c*) Professor Earl Logan, Jr.
(*d*) Experimental; applied research.
(*e*) Laboratory investigation of factors affecting noise generation in pumps, valves, lines and fittings of a hydraulic system immersed in water.

UNIVERSITY OF ARKANSAS, Civil Engineering Department, Fayetteville, Ark. 72701. Professor Hugh M. Jeffus, Associate Professor.

006-07920-860-33

MATHEMATICAL MODELING AND EVALUATION OF STREAM STORAGE POTENTIAL

(*b*) Office of Water Resources Research and the University of Arkansas.
(*d*) Applied research.
(*e*) The purpose of this investigation is to develop a mathematical model of the supply-storage potential of Arkansas streams and to evaluate the supply of water available.
(*g*) The results indicate that the storage size versus the probability of the reservoir contents being depleted for a given drift rate as determined by Moran's model of a dam can be approximated by three simple equations.

AUBURN UNIVERSITY, Department of Civil Engineering, Auburn, Ala. 36830. Dr. Fred J. Molz, Assistant Professor.

007-0153W-82-33

PHYSICAL AND SIMULATION MODELS OF THE SUBSURFACE HYDROLOGIC SYSTEM

(*b*) Office of Water Resources Research.
(*h*) See *Water Resources Research Catalog* **7**.

AVCO EVERETT RESEARCH LABORATORY, 2385 Revere Beach Parkway, Everett, Mass. 02149. Raymond B. Janney II, Assistant to the Director.

008-08579-020-18

ISOTROPIC TURBULENCE

(*b*) Advanced Research Projects Agency, Dept. of Defense, and Space and Missiles Systems Organization, Air Force Systems Command.
(*d*) Theoretical; applied.
(*e*) A simple form for the three-dimensional velocity spectrum function E(k) was proposed by von Karman (Proc. Nat. Acad. Sci., **34**, 1948). The purpose of this work is to furnish this form with a simple (exponential) viscous cutoff, and to examine some consequences of the resultant, more general expression for E(k).
(*f*) Completed.
(*g*) A simple form for the isotropic velocity fluctuation spectrum, has yielded a number of results consistent with turbulent flow measurements taken under a wide range of conditions. Two parameters specify the spectrum, one an absolute "mean strain-rate constant," the other the (variable) Reynolds number $R\lambda$; a value for the former parameter was obtained from low-speed grid flow data. Other approaches have appeared, notably the more mathematical one of Shkarofsky. However, the intent of this work is to provide a formulation more usable for calculational purposes. Its interesting features (e.g., use of Corrsin's cascade model, the exponential nature of the viscous cutoff region, comparisons with experiments) are not necessarily meant to be taken "seriously" at this time; at the very least, further experimental and theoretical developments are needed if they are ever to be tied into a larger framework.
(*h*) **Some Considerations of a Simplified Velocity Spectrum Relation for Isotropic Turbulence,** R. L. Schapker, *AIAA J.* **9**, No. 5, May 1971, pp. 952-955.

BATTELLE MEMORIAL INSTITUTE, Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201. R. L. Merrill, Director.

009-07969-630-27

HIGH SPEED VANE PUMP

(*b*) U.S. Air Force, Aero Propulsion Laboratory.
(*c*) D. L. Thomas, Research Engineer.
(*d*) Applied research and development.
(*e*) The program objective was to demonstrate a variable-displacement hydraulic vane pump capable of operating at 30,000 rpm, 4,000 psi, and 50 gpm on MIL H-5606B hydraulic fluid. The pump incorporated two unique concepts: (1) a pivoting-tip vane which provided full hydrodynamic lubrication between the rotating vanes and stationary cam ring, and (2) a deformable cam ring which provided a variable displacement capability with a hydrostatically balanced pump configuration.
(*f*) Continued development in a follow-on program.
(*g*) The pivoting-tip vanes were qualified in a test rig at maximum operating conditions. Over 38 hours running time

was obtained in actual pumps at speeds of 30,000 rpm. The maximum pressure obtained was 3,000 psi due to resonant vibration of the deformable cam ring. Further development work is in progress to overcome this problem.

(*h*) **30,000 RPM Vane Pump Demonstration,** D. L. Thomas, J. P. Dechow, et al., *AFAPL-TR-72-9*, Aero Propulsion Lab., WPAFB, Mar. 1972.

009-07970-630-15

TURBINE SPEED FUEL PUMP

(*b*) U.S. Army Aviation Material Laboratories.
(*c*) H. T. Johnson, Research Engineer.
(*d*) Applied research and development.
(*e*) The program objective was to develop a fixed displacement-vane fuel pump for small gas turbines capable of operating at 50,000 rpm, 650 psi, and 2,000 lb/hour on JP-4 fuel. A 200-hour endurance run was to be made at speeds from 25,000 to 40,000 rpm.
(*f*) Completed.
(*g*) All program objectives were obtained. Results verified that high speed operation can be achieved without sacrificing life.
(*h*) **Design and Evaluation of an Advanced High-Speed Fuel Pump,** H. T. Johnson, *USAAMRDL, Tech. Rept. 71-37*, AD 729 867, July 1971.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Division of Engineering and Applied Science, Engineering Science Department, Pasadena, Calif. 91109. Dr. Francis H. Clauser, Division Chairman.

011-01548-230-20

PROBLEMS IN HYDRODYNAMICS

(*b*) Office of Naval Research, Department of the Navy.
(*c*) Professor Milton S. Plesset.
(*d*) Theoretical and experimental; basic research.
(*e*) Studies of cavitating and noncavitating flow; dynamic behavior of cavitation bubbles; theoretical studies of cavitation damage.
(*h*) **The Tensile Strength of Liquids,** *Cavitation State of Knowledge, ASME Symp.*, pp. 15-25 (1969).

Cavitating Flows, *Topics in Ocean Engrg.*, Chap. 7 (Gulf Pub. Co., Houston, 1969).

Cavitation Erosion in Nonaqueous Liquids, *J. Basic Engrg., Trans. ASME* **92,** 4, pp. 807-814, Dec. 1970.

Behavior of Liquid Sodium in a Sinusoidal Pressure Field–Comments, M. S. Plesset, *J. Basic Engrg., Trans. ASME* **92,** 4, pp. 678-679, Dec. 1970.

On the Thermodynamics of Nucleation in Weak Gas-Liquid Solutions, *J. Basic Engrg., Trans. ASME* **92,** 4, pp. 701-702, Dec. 1970.

Physical Effects in Cavitating Flows, M. S. Plesset, *Symp. Proc. on Turbomachinery*, Penn. State Univ., 1970.

Collapse of an Initially Spherical Vapour Cavity in the Neighborhood of a Solid Boundary, M. S. Plesset, R. B. Chapman, *J. Fluid Mech.* **47,** 2, pp. 283-290, 1971.

Effect of Dissolved Gases on Cavitation in Liquids, M. S. Plesset, *Zeitschrift fur Flugwissenschaften* **19,** 3, pp. 120-121, Mar. 1971.

Nonlinear Effects in the Collapse of a Nearly Spherical Cavity, *J. Basic Engrg., Trans. ASME* (in press).

Thermal Effects in the Free Oscillation of Gas Bubbles, R. B. Chapman, M. S. Plesset, *J. Basic Engrg., Trans. ASME* (in press).

Temperature Effects in Cavitation Damage, M. S. Plesset, *J. Basic Engrg., Trans. ASME* (in press).

CALIFORNIA INSTITUTE OF TECHNOLOGY, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, Calif. 91103. Dr. W. H. Pickering, Laboratory Director.

012-07921-540-50

DYNAMICS OF JET IMPINGEMENT

(*b*) NASA-OAST (RP).
(*c*) Jack H. Rupe, Research Group Supervisor.
(*d*) Experimental investigation and analytical correlations; applied research.
(*e*) Studies of non-reactive sprays formed by impinging liquid jets form the basis for design criteria for elements of rocket engine injectors. In addition, an analytic description of the flow field produced by free liquid jets is sought.
(*g*) Comparisons of cold-flow mixing efficiency for sprays formed by unlike impinging doublet injector elements comprising circular and noncircular orifices have recently been reported by other investigators. It was concluded that noncircular elements produce significantly better mixing efficiencies, η_m, than a circular unlike doublet at equivalent design conditions. The fact that the η_m for the circular orifice unlike doublet was significantly lower than typical values for a number of other circular-orifice doublets suggested that factors other than orifice shape might have been present in the comparison. Experimental results of unlike doublet mixing obtained at this laboratory are correlated with an analytically derived equation predicting fluid cavitation. The correlation relates the minimum orifice pressure drop required to initiate cavitation to the system back pressure, cold flow simulant vapor pressure, and the orifice flow discharge and contraction coefficients. Stream flow instabilities are also visually correlated with cavitation and orifice discharge coefficient measurements. In addition, the influence of cavitation on the characteristic phenomena of hydraulic flip is observed for both circular and noncircular shaped orifices. For particular orifice lengths, some noncircular shapes are shown to produce more fully developed flows (shorter recovery lengths) and therefore provide slightly higher cold flow mixing uniformities than circular shaped orifices of equal length. The particular noncircular shaped elements evaluated, however, are shown to be more sensitive to liquid stream misimpingement than the corresponding circular orifices.
(*h*) **Liquid Phase Mixing of Bipropellant Doublets,** F. W. Hoehn, J. H. Rupe, J. G. Sotter, *JPL TR 32-1546*, 15 Feb. 1972. A paper based on this work was presented at the 8th JANNAF Liquid Propellant Combustion Instability Mtg., Los Angeles, Calif., Oct. 1971. Report available from Manager, Tech. Information and Documentation Div., JPL (see address above).

CALIFORNIA INSTITUTE OF TECHNOLOGY, Division of Engineering and Applied Science, W. M. Keck Laboratory of Hydraulics and Water Resources, Pasadena, Calif. 91109. Dr. Francis H. Clauser, Division Chairman.

013-04561-060-36

DYNAMICS OF DENSITY-STRATIFIED WATER RESERVOIRS

(*b*) Environmental Protection Agency, Water Quality Office.
(*c*) Professor Norman H. Brooks.
(*d*) Basic; theoretical and experimental.
(*e*) Reservoir mixing by pumping water from one level to another is being studied both by laboratory tank experiments and by computer simulation. The simulation technique predicts the response of the ambient density (or temperature) profile to the simultaneous effects of selective withdrawal from one layer, and discharge of the same fluid as a buoyant (or sinking) jet at a different level. The results will be useful in managing the quality of water in man-made lakes, in which bottom waters often become oxygen deficient in summer due to the thermal stratification.

517-020 O-LT - 74 - 2

(*f*) Inactive.

(*g*) The results of laboratory experiments and two field mixing experiments showed that the simulation technique predicts the response of the impoundment reasonably well.

(*h*) **Mixing of Density-Stratified Impoundments with Buoyant Jets,** John D. Ditmars, *W. M. Keck Lab. Rept. No. KH-R-22*, Sept. 1970, 203 pp.

013-07144-220-54

BASIC RESEARCH IN SEDIMENTATION

(*b*) National Science Foundation.

(*c*) Professors V. A. Vanoni, N. H. Brooks.

(*d*) Experimental and theoretical.

(*e*) Flume studies are made to determine the effect of water temperature on the characteristics of flows over sediment beds. This involves observations of flow resistance, bed form and sediment discharge.

(*g*) In flows over flat beds with very low rates of sediment movement the effect of water temperature can be expressed in terms of the boundary Reynolds number, $R = U\tau\, d_s/\nu$ in which $U\tau$ = shear velocity, d_s = median size of sediment and ν = kinematic viscosity of the water. An increase in water temperature will result in an increase in sediment discharge when R is less than 10, an increase in sediment discharge when R lies between 10 and 200 and no change in sediment discharge when R exceeds 200.

(*h*) Discussion of **Indeterminate Hydraulics of Alluvial Channels,** B. D. Taylor, *J. Hydraul. Div., ASCE* **97,** HY5, May 1971, pp. 756-760.

Discussion of **Initiation of Ripples on Flat Sediment Beds,** B. D. Taylor, *J. of Hydraul. Div., ASCE* **97,** HY11, Nov. 1971, pp. 1924-1930.

Temperature Effects in Alluvial Streams, B. D. Taylor, *W. M. Keck Lab. Rept. No. KH-R-27*, 1971.

013-07146-020-36

MIXING IN RIVERS AND ESTUARIES

(*b*) EPA, WQO.

(*c*) Professor Norman H. Brooks.

(*d*) Experimental and theoretical research.

(*e*) Previous research on longitudinal dispersion in natural channels (by Fischer) demonstrated the importance of transverse turbulent diffusion as part of the mechanism of longitudinal dispersion or mixing. Two types of flume experiments on transverse diffusion are being conducted. Internal seiching and interfacial mixing in stratified lakes, and salt water intrusion in estuaries are also being studied.

(*g*) In the first kind of experiments (by Okoye), a plume of neutrally buoyant tracer was released at a point on the centerline of the flow in a wide flume. The distribution of tracer in downstream cross-sections is measured with in-situ probes and with overhead photographs. The results give the total transverse diffusion coefficient, and its decomposition into plume growth and plume meandering. In the second kind of experiments (by Prych), the tracer is either heavier or lighter than the ambient water, and the injector is a full-depth slit. The density difference accelerates the lateral spreading significantly during the early stages by gravity-driven secondary currents. The excess spreading due to density difference can be related in a dimensionless manner to a source strength parameter and injector width-to-depth ratio. Experiments (by Sullivan) have investigated the Lagrangian correlation coefficients in Taylor dispersion in open channel flows. The dispersion of floating objects on the surface of open channel flows has been studied by Cederwall. Interfacial mixing in stratified lakes and estuaries is being studied experimentally to determine the effect of density stratification on turbulent mixing.

(*h*) **Characteristics of Transverse Mixing in Open-Channel Flows,** J. K. Okoye, *W. M. Keck Lab. Rept. No. KH-R-23*, Nov. 1970, 269 pp.

Effects of Density Differences on Lateral Mixing in Open-Channel Flows, E. A. Prych, *W. M. Keck Lab. Rept. No. KH-R-21*, May 1970, 225 pp.

A Numerical Solution of the Two-Dimensional Diffusion Equation in a Shear Flow, J. F. Coudert, *W. M. Keck Lab. Tech. Memo 70-7*, June 1970, 38 pp.

Longitudinal Dispersion Within a Two-Dimensional Turbulent Shear Flow, P. J. Sullivan, *J. Fluid Mech.* **49,** 3, Oct. 15, 1971, pp. 551-576.

Some Data on the Distance-Neighbour Function for Relative Diffusion, P. J. Sullivan, *J. Fluid Mech.* **47,** 3, June 14, 1971, pp. 601-607.

Float Diffusion Study, K. Cederwall, *Water Research* **5,** Nov. 1971, pp. 889-907. (Also *W. M. Keck Lab. Tech. Memo 71-1*, Apr. 1971.)

Internal Seiches and Interfacial Mixing in Stratified Lakes, R. R. Rumer, Jr., *W. M. Keck Lab. Tech. Memo 71-3*, July 1971, 39 pp.

013-07147-060-36

TURBULENT BUOYANT PLUMES AND JETS

(*b*) EPA, WQO.

(*c*) Professor Norman H. Brooks.

(*d*) Theoretical and experimental laboratory research.

(*e*) Problems of buoyant jets and plumes in density-stratified environments are being investigated for both two- and three-dimensional cases. Laminar cases are studied as well as turbulent. The results are applicable to certain problems of waste water or cooling water disposal in lakes, estuaries, and the ocean.

(*g*) The analysis of air bubble plumes in density-stratified environments using an integral technique that includes air compressibility and differential bubble and liquid velocities has been carried out. Cederwall has studied buoyant slot jets into stagnant or flowing environments. Sullivan has considered the penetration of a density interface by heavy negatively buoyant vortex rings with possible application to ocean dumping of heavy liquid wastes. The behaviour of laminar momentum jets in density-stratified environments has been analyzed and the results are being extended to turbulent jets. Brooks has prepared a set of lecture notes on the conceptual design of submarine outfalls using the principles developed in buoyant jet research.

(*h*) **Analysis of Air-Bubble Plumes,** K. Cederwall, J. W. Ditmars, *W. M. Keck Lab. Rept. No. KH-R-24*, Sept. 1970, 51 pp.

A Buoyant Slot Jet Into Stagnant or Flowing Environment, K. Cederwall, *W. M. Keck Lab. Rept. No. KH-R-25*, Mar. 1971, 86 pp.

Computer Program for Slot Buoyant Jets Into Stratified Ambient Environments, C. A. Sotil, *W. M. Keck Lab. Tech. Memo 71-2*, June 1971, 35 pp.

The Penetration of a Density Interface by Heavy Vortex Rings, P. J. Sullivan, submitted to *J. Fluid Mech.* (May 1971).

Laminar Momentum Jets in a Stratified Fluid, E. J. List, *J. Fluid Mech.* **45,** Feb. 15, 1971, pp. 561-574.

Lecture Notes on Conceptual Design of Submarine Outfalls, N. H. Brooks, Univ. of Calif. at Berkeley, *Water Res. Engrg. Educational Series, Program VII, Pollution of Coastal and Estuarine Waters*, Jan. 29-30, 1970, (Pt. I, 25 pp., Pt. II, 12 pp.). Available as *W. M. Keck Lab. Tech. Memos 70-1 and 70-2*.

Horizontal Surface Discharge of Warm Water Jets, K. Cederwall, *J. Power Div., ASCE* **97,** PO1, Jan. 1971, pp. 229-234.

Technical Aspects of Waste Disposal in the Sea Through Submarine Outlets, H. B. Fischer (Univ. of Calif. at Berkeley) and N. H. Brooks, presented at the *FAO Tech. Conf. on Marine Pollution and Its Effects on Living Resources and Fishing, Paper FIR; MP/70/R-4*, Dec. 1970, 16 pp.

Dispersion Phenomena in Coastal Waters, K. Cederwall, presented as John Freeman Memorial Lecture, *J. Boston Soc. Civil Engrg.* **57,** 1, 1970, pp. 34-70.

013-07922-470-10

WAVE-INDUCED OSCILLATIONS IN ARBITRARY SHAPED HARBORS

(*b*) Dept. of the Army, Corps of Engineers.
(*c*) Professor Fredric Raichlen or Dr. Jiin-jen Lee.
(*d*) Experimental and theoretical research.
(*e*) The objective of this research was to study the wave-induced oscillations of harbors of arbitrary shapes both theoretically and experimentally. Attention was directed in later phases of this investigation to the coupling of harbors. An analytical technique was developed to treat harbors consisting of coupled basins connected to the open sea. The analysis results in a saving of both computer storage and computing time for the solution of the response of an arbitrary shaped harbor that could be divided into two coupled basins compared to treating the harbor as a single basin. The reduction in computer storage is particularly important considering the response to waves which are short compared to dimensions of the harbor. This study has shown that the response of a simple harbor to periodic incident wave system is significantly modified by the addition of a coupled basin. It appears that the response curve for such a harbor can be synthesized from the response of the individual basins. This may allow an approximate response curve to be constructed for a complex harbor from a knowledge of the approximate response of parts of the total harbor.
(*f*) Completed.
(*h*) **Wave Induced Oscillations in Harbors with Connected Basins,** J. J. Lee, F. Raichlen, *W. M. Keck Lab. Rept. No. KH-R-26*, Aug. 1971.
Oscillations in Harbors with Connected Basins, J. J. Lee, F. Raichlen, *J. Waterways and Harbors Div., ASCE* (in press).

013-07923-420-54

GENERATION AND COASTAL EFFECTS OF TSUNAMIS

(*b*) National Science Foundation.
(*c*) Professor Fredric Raichlen or Dr. Joseph L. Hammack, Jr.
(*d*) Experimental and theoretical research.
(*e*) Waves are generated at one end of a wave tank by the programmed displacement of a section of the bottom. A linear theory has been developed which predicts quite well the characteristics of the wave in the region of the generator. It has been found that for the two types of time-histories employed for both positive and negative movements of the bottom, the maximum amplitude of the wave that emanates from the generation area is at most 50 percent of the displacement of the bottom. A theoretical approach has been used to propagate these waves over long distances which includes both nonlinear effects and the effects of vertical accelerations. Good agreement has been found between theory and experiment in this phase of the study. The results of this study have been applied to an actual earthquake to yield information on the gross characteristics of the generated wave system.
(*h*) **Tsunamis; Some Laboratory and Field Observations,** F. Raichlen, *Proc. 11th Intl. Conf. Coastal Engrg.*, Washington, D.C., Sept. 1970.
Tsunami Generation and Near-Field Propagation, J. L. Hammack, Jr., F. Raichlen, *Proc. 13th Intl. Conf. Coastal Engrg.*, Vancouver, B.C., Canada, July 1972.
Tsunamis–A Model of Their Generation and Propagation, J. L. Hammack, Jr., *W. M. Keck Lab. Rept. KH-R-28*, May 1972.

013-07924-430-54

THE STABILITY OF ROCK PAVEMENTS EXPOSED TO WAVES

(*b*) National Science Foundation.
(*c*) Professor Fredric Raichlen or Mr. Ehud Naheer.
(*d*) Experimental and theoretical research.
(*e*) This research is directed toward an understanding of the forces and moments acting on large material (such as rock) on the bottom due to breaking and near-breaking wave systems. In engineering projects this material might be used to design the armor for preventing local erosion at pipelines or structures which pass through the surf zone. Initial studies are being conducted in a large wave tank where a solitary and a regular wave generator are available. The wave tank can be tilted so that a breaking wave system can be produced at a specified location. Forces will be measured on instrumented particles and the incipient motion of particles will be observed in a way which is similar to that used in studying sediment transportation in unidirectional flows.
(*h*) **Wave Protection for Ocean Outfalls,** F. Raichlen, N. H. Brooks, *Proc. 13th Intl. Conf. Coastal Engrg.*, Vancouver, B.C., Canada, July 1972.

CALIFORNIA STATE UNIVERSITY, SACRAMENTO, Department of Civil Engineering, 6000 Jay Street, Sacramento, Calif. 95819. Norman J. Caspellan, Department Chairman.

014-07624-300-60

FLOODPLAINS ORCHARD MODEL STUDY

(*b*) State of California Reclamation Board.
(*c*) Dr. Alan L. Prasuhn or Prof. William R. Neuman.
(*d*) Experimental; applied research.
(*e*) A model study was conducted of overbank flood flows through orchards planted along the Sacramento and Feather Rivers on the river side of the levees. The existing tree configuration required by the California Reclamation Board was compared to a hedgerow configuration proposed by the orchardists. Nonalignment of the flow with the tree rows and flow depth relative to tree height were also studied. Model trees consisting of pipe cleaners twisted together were compared in individual drag tests to a carefully scaled model pear tree.
(*f*) Completed.
(*g*) It was found that if the design flood flow was above the tree tops only a small increase in resistance and therefore depth could be expected with the new tree configuration. If the maximum flow was to be within the tree limits very large increases in resistance and depth could occur. Manning's n was found to increase continuously with depth within the tree height. Above the trees n decreased with increasing depth. The model was verified by comparison with historic computations on the two rivers.
(*h*) **Proposed Orchard Standards,** *Report to California Reclamation Board*, April 1969.
Discussion of **Hydraulic Problems Related to the Passage of Highwater Waves in the Flood Bed,** Oden Storosolsky, by A. L. Prasuhn, W. Neuman, *Proc. 14th Congr. IAHR*, Paris, Sept. 1971.

014-07625-220-80

RELATIONSHIPS OF SEDIMENT TRANSPORT TO BED FORMS AND TURBULENCE LEVELS

(*b*) California State University Foundation, Sacramento.
(*d*) Experimental; basic research.
(*e*) A constant-temperature anenometer with a conical probe is being used to obtain turbulence measurements in water flows over sand beds.
(*g*) Changes in turbulent and mean velocity profiles have been correlated with flow parameters and bed forms. The presence of high sediment concentrations appears to suppress the turbulence levels near the bed and to increase them nearer the surface.
(*h*) Discussion of **Experimental Investigation of Form of Bed Roughness,** S. D. Khanna, *J. of Hyd. Div., Proc. ASCE*, Oct. 1970., by A. L. Prasuhn, *J. of Hyd. Div., ASCE* **97**, pp. 91146-1148, July 1971.
Turbulence Measurements Over an Alluvial Bed, A. L. Prasuhn, R. Lerseth, *Sedimentation (Symp. to Honor Prof. H. A. Einstein)*, pp. 7-1 to 7-15, 1972.

014-08262-810-44

ECONOMIC SIGNIFICANCE OF WATER RESOURCE FORECASTS AT VARIOUS LEVELS OF PROBABLE FORECAST ERROR

(*b*) U.S. Weather Service.
(*c*) Dr. Murland R. Packer.
(*d*) Theoretical; applied research.
(*e*) This study represents Phase I of a three-phase project. Phase I has been concerned with developing and evaluating the basic relationship between streamflow forecast errors and the parameters which may be able to predict those errors; establishing a procedure for determining the error probability associated with a given streamflow forecast.

014-08263-350-00

FLOW UNDER A RADIAL GATE

(*c*) Dr. Alan L. Prasuhn.
(*d*) Experimental; Master's thesis.
(*e*) A new mathematical model has been developed for flows under a radial gate with submerged discharge. The resulting expression is being correlated with experimental data.

014-08264-040-60

CIRCULATION IN THE SAN FRANCISCO BAY SYSTEM AND ITS EFFECTS ON DISPERSION

(*b*) Dept. of Water Resources, State of California.
(*c*) Richard J. Lerseth, Asst. Engineer, Dept. of Water Resources, Sacramento, Calif., or Dr. A. L. Prasuhn, Dept. of Civil Engrg., Calif. State Univ., Sacramento.
(*d*) Experimental, program development and operation of model, for Master's thesis.
(*e*) Determination of the circulation pattern and dispersion characteristics of the San Francisco Bay System due to tidal effect, wind, and Coriolis forces. Net effect of advective flows from rim sources.

UNIVERSITY OF CALIFORNIA, BERKELEY, College of Engineering, Department of Civil Engineering, Division of Hydraulic and Sanitary Engineering, Berkeley, Calif. 94720. Professor J. W. Johnson.

015-01554-860-60

SEAWATER CONVERSION RESEARCH

(*b*) State of California.
(*c*) Professor Alan D. K. Laird, Coordinator, Saline Water Conversion Research, Univ. of Calif., 1301 S. 46th St., Richmond, Calif. 94804.
(*e*) The purpose of this project is to do research toward making available methods for the large-scale, low-cost demineralization of seawater. The project includes a number of investigations, of which the following have been active during 1970-1972: (1) multiple-effect flash evaporator; (2) vapor compression distillation; (3) studies of heat transfer and scaling in distillation equipment; (4) transport phenomena near a liquid-vapor interface; (5) thermodynamic and economic analyses; (6) studies of the thermodynamic properties of seawater; (7) solar distillation; (8) fundamental studies of corrosion processes; (9) electrodialysis; (10) reverse osmosis; (11) ion exchange; and (12) geothermal desalination. Investigations are carried on at the Berkeley, Los Angeles, Riverside, San Diego and Santa Barbara campuses.
(*g*) Detailed results may be obtained from the progress reports and publications listed under (h) below. This project has been active since 1951-52 and previous summaries have listed all reports prior to Jan. 1970.
(*h*) Reports and publications since January 1970 summarizing the work to date:

University of California, Los Angeles:

Submerged Combustion, P. A. Iyer, C. Chu, *WRC Rept. No. 37*, *UCLA 70-8*, Jan. 1970.

The Multistage Flash Desalting Process–Its Commercial Applications, N. A. El-Ramly, J. M. English, J. W. McCutchan, *WRC Rept. No. 38*, *UCLA-Eng-7079*, Aug. 1970.

Saline Water Research Progress Summary, January 1, 1970-December 31, 1970, Staff, *WRC Rept. No. 40*, *UCLA-Eng-7101*, Jan. 1971.

Selectivity of Cellulose Acetate Membrane for the Bivalent Cations-Mg^{++} and Ca^{++}, B. M. Misra, J. W. McCutchan, *WRC Rept. No. 42*, *UCLA-Eng-7137*, Sept. 1971.

Preparation and Performance of Cellulose Acetate Semipermeable Membranes for Sea Water Service, J. S. Johnson, J. W. McCutchan, D. N. Bennion, *WRC Rept. No. 43*, *UCLA-Eng-7139*, June 1971.

Selectivity of Cellulose Acetate Membranes for the Anions NO_3^-, SO_4^{2-}, PO_4^{3-} and $AsO4^{3-}$, C. Kamizawa, J. W. McCutchan, *WRC Rept. No. 44*, *UCLA-Eng-7158*, Oct. 1971.

Systems Analysis and Optimization of a Tubular Module Reverse Osmosis Pilot Plant for Sea Water Desalination, V. Goel, J. W. McCutchan, *WRC Rept. No. 45*, *UCLA-Eng-7163*, Oct. 1971.

Saline Water Research Progress Summary, January 1, 1971-December 31, 1971, Staff, *WRC Rept. No. 47*, *UCLA-Eng-7201*, Jan. 1972.

Optimal Conjunctive Use of Desalinized Surface and Ground Water, F. Mobasheri, J. M. English, *Proc. 3rd Intl. Symp. on Fresh Water from the Sea* **3**, pp. 179-192, 1970.

Technological Progress in Desalting; Its Measurement and Cost, N. A. El-Ramly, J. M. English, *Proc. 3rd Intl. Symp. on Fresh Water from the Sea* **3**, pp. 433-447, 1970.

Reverse Osmosis at Coalinga, California, J. W. McCutchan, J. S. Johnson, *Amer. Water Works Assoc.*, pp. 346-353, June 1970.

Electrochemical Characteristics of Iron. Effect of Heat Treatment and Iron Purity, A. Akiyama, R. E. Patterson, K. Nobe, *Corrosion* **26**, pp. 51-57, 1970.

Kinetics of the Hydrogen Evolution Reaction on Titanium, N. T. Thomas, K. Nobe, *J. Electrochem. Soc.* **117,** pp. 622-626, 1970.

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Corrosion Inhibition of Zone-Refined Iron by Ring-Substituted Benzoic Acids, A. Akiyama, K. Nobe, *Corrosion*, Oct. 1970.

Mass Transfer of Binary Electrolytes in Membranes at High Concentration, J. C. Osborn, D. N. Bennion, *Ind. Eng. Chem. Fund.* **64,** pp. 273-280, 1971.

Submerged Combustion, P. A. Iyer, C. Chu, *Desalination* **9,** p. 19, Mar. 1971.

Laminar Film Condensation from a Steam-Air Mixture Undergoing Forced Flow Down a Vertical Surface, V. E. Denny, A. F. Mills, V. J. Jusionis, *J. Heat Transfer* **93,** pp. 297-304, 1971.

Optimum Conjunctive Use of a Dual-Purpose Desalting Plant and a Surface Water Reservoir, F. Mobasheri, R. Harboe, *Desalination* **9,** 2, p. 141, June 1971.

Alkaline Scale Abatement by Carbon Dioxide Injection, R. Ellis, J. Glater, J. W. McCutchan, *Environmental Sci. and Tech.* **5,** p. 350, 1971.

Effect of Benzoate and Chloride Ions on Passive Ion in Alkaline Solutions, O. Lahodny, K. Nobe, *Corrosion* **27,** pp. 239-240, 1971.

Polarization of Copper in Acidic and Alkaline Solutions, C. Kim, K. Nobe, *Corrosion* **27,** pp. 382-385, 1971.

*Requests for copies of reports should be directed to: Water Resources Center, Publication Div., 2066 Engineering I, Univ. of Calif., Los Angeles, Calif. 90024. Requests for copies of publications should be directed to: Publications, School of Engrg. and Applied Science, 5532 Boelter Hall, Univ. of Calif., Los Angeles, Calif. 90024.

University of California at Berkeley:**

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1971 Annual Report, Staff, *WRC Rept. No. 46, SWCL Rept. No. 72-1*, 73 pp., Jan. 1972.
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Dielectric Cell for Radio-Frequency Measurement of Conductive Media, S. B. Sachs, A. Katchalsky, K. S. Spiegler, *Electrochimica Acta* **15,** p. 693, 1970.
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Polarization at Ion Exchange Membrane-Solution Interfaces, K. S. Spiegler, *Desalination* **99,** pp. 367-385, 1971.
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**Requests for copies should be directed to: Sea Water Conversion Lab., Univ. of Calif., 1301 S. 46th St., Richmond, Calif. 94804.

015-02265-030-00

FORCES ON ACCELERATED CYLINDERS

(*c*) Professor A. D. K. Laird. (See (01554).)
(*d*) Experimental and theoretical; basic research.
(*e*) Measurement and prediction of drag coefficients and flow configurations about cylinders in fluids, including effects of support flexibility.
(*g*) Analytical explanation of eddy formation found.
(*h*) **Eddy Formation Behind Circular Cylinders,** A. D. L. Laird, *J. Hydraul. Div., Proc., ASCE* **97,** Paper 8170, HY6, pp. 763-775, June 1971. Copies available from the publisher.

015-04930-410-11

COASTAL SAND MOVEMENT

(*b*) U.S. Army Coastal Engrg. Res. Center.
(*d*) Experimental; laboratory and field.
(*e*) This investigation is concerned with the transportation of sand by both wind and waves.
(*h*) **Equilibrium Profiles of Model Beaches,** I. V. Nayak, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-2-25*, 117 pp., 1970.
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Recent Sediments of the Central California Continental Shelf, Pigeon Point to Sand Hills Bluffs, Part A. Introduction and Grain Size Data, J. Lee, T. Yancey, P. Wilde, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-2-28*, 62 pp., 1970.
Faunal Communities on the Central California Continental Shelf near San Francisco; A Sedimentary Environmental Study, T. Yancey, P. Wilde, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-2-29*, 65 pp., 1970.
Recent Sediments of the Central California Continental Shelf, Pillar Point to Pigeon Point, Part B. Mineralogical Data, J. Lee, M. Glogoczowski, T. Yancey, P. Wilde, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-2-30*, 63 pp., 1971.
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Quarternary Beaches and Coasts Between the Russian River and Drakes Bay, California, C. R. Minard, Jr., *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-2-35*, 206 pp., 1971.
River Mouth and Beach Sediments–Russian River, California to Rogue River, Oregon. Part A. Introduction and Grain Size Analyses, M. Glogoczowski, P. Wilde, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-2-36*, 73 pp., 1971.

015-04932-820-33

GROUNDWATER BASIN MANAGEMENT

(*b*) Office of Water Resources Research; Water Resources Center.
(*c*) D. K. Todd.
(*d*) Theoretical; applied research.
(*e*) Equations were derived and solved to study the dispersion of the fresh-salt water interface due to tidal fluctuations in a confined aquifer. The goal is a generalized mathematical model describing a two-dimensional aquifer system, the longitudinal and transverse dispersion coefficients, and the dispersion caused by local movements of the interface and by tidal fluctuations.
(*f*) Completed.

015-04934-420-11

WAVE DIFFRACTION AND REFRACTION

(*b*) U.S. Army Coastal Engrg. Res. Center.
(*c*) Professor R. L. Wiegel.
(*d*) Experimental and theoretical; basic research.
(*e*) Determination by model tests of diffraction and refraction characteristics of wind waves. Computer simulation program for waves with directional spectra.
(*f*) Completed.
(*g*) A study was made on the directional spectra of wind generated waves, and on their diffraction by a semi-infinite breakwater. Theoretical studies are being conducted on the properties of direction of wave spectra, and methods of simulating such waves on a digital computer.
(*h*) **Determination of Directional Spectra of Ocean Waves from Gage Arrays,** N. N. Panicker, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-1-18*, 315 pp., 1971; also, *Ph.D. Thesis*, Dept. of Civil Engrg., Univ. of Calif., Berkeley.
Directional Spectra from Wave-Gage Arrays, N. N. Panicker, L. E. Borgman, *Proc. 12th Conf. Coastal Engrg., ASCE* **1**, pp. 117-136, Sept. 13-18, 1970, Washington, D.C.

015-05438-300-11

SHAPE OF CROSS SECTIONS IN RIVER BENDS

(*b*) Water Resources Center, Univ. of Calif.; U.S. Army Corps of Engineers.
(*c*) Professor H. A. Einstein.
(*d*) Experimental, statistical, basic research.
(*e*) A circular flume is used to establish for various flows the shape of the sediment bottom. Using the predictions of the velocity components by Rozovskii the equilibrium condition of the rolling sediment particle is used to predict the local cross slope of the bed and from that the shape of the section. 2300 cross-sections from the Missouri River are analyzed statistically to find the shape change in finite length bends. The influence of the channel bends is well documented; the influence of other variables such as channel width, slope, sediment size, discharge, etc., could not be established from the data available.
(*g*) The methods described under (e) permit prediction of the sections in the laboratory flume and for the particular river condition the shape of all sections as a function of curvature. It will be attempted in the future to combine the two methods of approach.
(*h*) **Prediction of the Shape of Improved Alluvial Channels from Existing Such Channels,** H. A. Einstein, A.-L. C. Hsieh. Publishing House of the Hungarian Academy of Sciences. English reprints available.
Stable Bed Profiles in Continuous Bends, M. El-Khudairy, *Ph.D. Thesis* and *Engrg. Lab. Rept. HEL-6-31*, Univ. of Calif., Berkeley, 103 pp., 1970.

015-05439-430-11

WAVE FORCES

(*b*) U.S. Army Coastal Engrg. Res. Center.
(*c*) Professor R. L. Wiegel.
(*d*) Experimental and theoretical; basic research.
(*e*) Determine by model tests the forces exerted by waves on coastal structures, including pipelines. Theoretical studies of statistical properties of wave forces.
(*g*) Forces exerted by waves on pipelines are being studied experimentally. The relationship between the Keulegan number, the longitudinal and transverse forces exerted by waves on piles is also being studied in the laboratory.
(*h*) **Wave Forces on a Circular Pile Due to Eddy Shedding,** D. D. Bidde, *Ph.D. Thesis*, Dept. of Civil Engrg., Univ. of Calif.,Berkeley, June 1970; also, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-9-16*, 141 pp., 1970.
Laboratory Study of Lift Forces on a Circular Pile, D. D. Bidde, *J. Waterways, Harbors and Coastal Engrg. Div., Proc. ASCE* **97**, WW4, pp. 595-614, 1971.
Wave-Induced Eddies and "Lift" Forces on Circular Cylinders, R. L. Wiegel, R. C. Delmonte, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-9-19*, 40 pp., 1972.
Preliminary Report on An Analysis of Project II Data (Wave Forces on a Pile), Hurricane Carla, Gulf of Mexico, F. M. Abdel-Aal, R. L. Wiegel, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-9-18*, 39 pp., 1971.

015-06223-020-61

THE MANAGEMENT OF SURFACE WATER HYDROLOGIC SYSTEMS FOR WATER QUALITY CONTROL

(*b*) Water Resources Center, Univ. of California.
(*c*) Hugo B. Fischer, Assoc. Professor.
(*d*) Experimental and theoretical; basic research.
(*e*) Basic mechanics of mixing and dispersion of pollutants in river and estuarine systems are studied to improve methods of predicting and managing surface water quality.
(*h*) **Analysis of the Use of Distorted Hydraulic Models for Dispersion Studies,** H. B. Fischer, E. R. Holley, *Water Resources Research* 7, pp. 46-51, 1971.

015-06224-420-11

TSUNAMIS

(*b*) U.S. Army Coastal Engrg. Res. Center.
(*c*) Professor R. L. Wiegel.
(*d*) Experimental and theoretical; basic research.
(*e*) Model and theoretical studies of water waves generated by horizontal fault moving normal to a channel or escarpment, and generated by a rockfall into a reservoir.
(*g*) See (e).
(*h*) **Hydraulic Model of Landslide-Generated Waves in Bays,** E. H. Kuba, *Shore and Beach* **37**, 1, pp. 49-54, 1969.
Theory of Water Waves Generated by a Time-Dependent Boundary Displacement, E. Noda, *Ph.D. Thesis*, Dept. of Civil Engrg., Univ. of Calif., Berkeley, 225 pp., 1969; also, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-16-5*, 225 pp., 1969.
Waterwaves Generated by Landslides in Reservoirs, R. L. Wiegel, E. K. Noda, E. M. Kuba, D. M. Gee, G. T. Tornberg, *J. Waterways, Harbors and Coastal Engrg. Div., Proc. ASCE* **96**, WW2, pp. 307-333, 1970.
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Theory of Water Waves Generated by Landslides, E. Noda, *J. Waterways, Harbors and Coastal Engrg. Div.*, Proc. ASCE **96,** WW4, pp. 835-855, 1970.
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A Study of Water Waves Generated by Tectonic Displacements, W. J. Garcia, Jr., *Ph.D. Thesis*, Dept. of Civil Engrg., Univ. of Calif., Berkeley, 114 pp., 1972; also, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-16-9*, 114 pp., 1972.

015-07148-400-54

MIXING PROCESSES IN ESTUARIES

(*b*) National Science Foundation.
(*c*) Hugo B. Fischer, Assoc. Professor.
(*d*) Experimental and theoretical; basic research.
(*e*) Studies are made of the convective and diffusive patterns in estuaries to find ways of predicting pollutant concentrations.
(*h*) **Dispersion in Homogeneous Estuary Flow,** E. R. Holley, D. R. F. Harleman, H. B. Fischer, *J. Hyd. Div., Proc. ASCE* **96,** HY8, pp. 1691-1709, 1970.

015-07149-060-36

MANAGEMENT OF WATER QUALITY IN STRATIFIED RESERVOIRS

(*b*) Environmental Protection Agency.
(*c*) Hugo B. Fischer, Assoc. Professor.
(*d*) Experimental and theoretical; basic research.
(*e*) The withdrawal layer in a stratified reservoir is being restudied to assess the effects of inertia as well as buoyancy.
(*h*) **Selective Withdrawal from a Stratified Reservoir,** J. Imberger, H. B. Fischer, *EPA Rept. 15040 EJZ 12/70*, 104 pp., Washington, D.C., 1970.

015-07150-820-54

OPTIMAL DETERMINATION OF STRATIFIED GROUND-WATER BASIN CHARACTERISTICS

(*b*) Natl. Science Found.; Water Resources Center.
(*c*) D. K. Todd.
(*d*) Theoretical; applied research.
(*e*) To estimate from historical data, values of S and T for individual wells in a given configuration for the purpose of optimal management of the basin. A computational algorithm will be designed, and it is proposed to solve it by decomposition because of its high dimensionality.

015-07151-870-61

WASTE DISPOSAL SYSTEMS

(*b*) Water Resources Center.
(*c*) Prof. R. L. Wiegel.
(*d*) Experimental, basic and applied research.
(*e*) Perform model studies of the mixing processes associated with sewage effluent being discharged on ocean bottom and buoyant power plant cooling water being discharged at ocean surface.
(*g*) Model studies of the interaction of numerous jets issuing from a manifold are being studied.
(*h*) **Mixing of Merging Buoyant Jets from a Manifold in Stagnant Receiving Water of Uniform Density,** P. Liseth, *Ph.D. Thesis*, Dept. of Civil Engrg., Univ. of Calif., Berkeley, 181 pp., 1970; also, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-23-1*, 181 pp., 1970.
Conical Hot-Film Anemometer in Jets in Salt Water, R. Dornhelm, M. Nouel, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-23-2*, 31 pp., 1970.
Velocity and Temperature in a Buoyant Surface Jet, R. Dornhelm, M. Nouel, R. L. Wiegel, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-23-3*, 62 pp., 1970.

015-08046-870-61

THE MECHANICS OF HEAT DISPOSAL IN STREAMS AND ESTUARIES

(*b*) Water Resources Center, Univ. of California.
(*c*) Hugo B. Fischer, Assoc. Professor.
(*d*) Experimental; basic research.
(*e*) An experimental study is underway of a buoyant surface jet exiting into flowing water.

015-08047-410-11

TIDAL INLETS ON SANDY SHORELINES

(*b*) Corps of Engineers, U.S. Army, Coastal Engrg. Res. Center.
(*d*) Experimental; laboratory and field; applied research.
(*e*) This investigation is concerned with the hydraulic and physical characteristics of tidal inlets on sandy shorelines.
(*h*) **Tidal Prism-Area Relationship in a Model Inlet,** I. V. Nayak, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-1*, 43 pp., 1971.
Shoreline Changes–Humboldt Bay, California, R. M. Noble, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-2*, 36 pp., 1971.
Bottom Sediment Characteristics Near Entrance to San Francisco Bay, J. W. Johnson, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-3*, 27 pp., 1971.
Field and Laboratory Studies–Navigation Channels of the Columbia River Estuary, M. P. O'Brien, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-4*, 34 pp., 1971.
Notes on Tidal Inlets on Sandy Shores, M. P. O'Brien, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-5*, 52 pp., 1971.
Memorandum Regarding James B. Eads' Contribution to the Design of Tidal Inlets, M. P. O'Brien, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-6*, 27 pp., 1971.
Selected Bibliography on the Engineering Characteristics of Coastal Inlets, P. F. Castaner, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-7*, 24 pp., 1971.
The Influence of Bed Material Size on the Tidal Prism-Area Relationship in a Tidal Inlet, R. C. Delmonte, J. W. Johnson, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-8*, 13 pp., 1971.
Summary of Annual Wave Power for Ten Deep-Water Stations Along the California, Oregon, and Washington Coasts, J. W. Johnson, J. T. Moore, F. B. Orrett, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-9*, 241 pp., 1971.
A Critical Review of the E. I. Brown Analysis of Inlets on Sandy Coasts, M. P. O'Brien, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-10*, 35 pp., 1971.
Closure of a Two-Dimensional Tidal Inlet with a Steady Ebb Flow, J. T. Moore, J. W. Johnson, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-11*, 12 pp., 1972.
Tidal Inlets on the California, Oregon, and Washington Coasts, J. W. Johnson, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-12*, 156 pp., 1972.
The Influence of Bed Material Size on the Tidal Prism-Area Relationship in a Tidal Inlet, J. T. Moore, *Univ. of Calif. Hyd. Engrg. Lab. Rept. HEL-24-13*, 9 pp., 1972.

UNIVERSITY OF CALIFORNIA, DAVIS, College of Agricultural and Environmental Sciences, Department of Water Science and Engineering, Davis, Calif. 95616. James N. Luthin, Department Chairman.

016-05145-810-33

GENERALIZED ANALYSIS OF SMALL WATERSHED RESPONSES

(*b*) OWRR, Water Resources Center, Univ. of California.
(*c*) Professor J. Amorocho.

(*d*) Theoretical and experimental; basic and applied research.
(*e*) Studies on the mathematical theory of nonlinear systems with lumped and with distributed parameters; development of methods for the establishment of inflow-outflow relationships for natural catchments; laboratory and field investigations related to above.
(*f*) Terminated.
(*g*) A method for the determination of nonlinear response functions of small watersheds was developed and tested in laboratory catchments and in natural catchments.
(*h*) **Generalized Analysis of Small Watershed Responses,** A. Brandstetter, J. Amorocho, *Water Sci. and Engrg. Paper No. 1035*, June 1970.
Determination of Nonlinear Functional Response Functions in Rainfall-Runoff Processes, J. Amorocho, A. Brandstetter, *Water Resour. Res.* **7,** 5, Oct. 1971.

016-06665-860-00

OPTIMIZATION OF CONJUNCTIVE SURFACE AND GROUNDWATER USE

(*c*) Dr. Verne H. Scott and Dr. Gert Aron.
(*d*) Theoretical and field research. Applied research; Doctoral thesis.
(*e*) Development of an operating schedule of a water distribution system including surface and groundwater supplies for the purpose of optimizing long-term benefits; a study of water quality control by programmed conjunctive use of water supplies of different salt content.
(*f*) Terminated.
(*g*) The problems and available methods of optimizing the operation of a water resource system involving groundwater use and recharge, local surface supply and an imported supply were outlined with particular emphasis on the technique of dynamic programming. Simplification of a large and complex system and subdivision of the system into various subsystems was suggested. Several methods of optimizing the operation were presented. Dynamic programming was proposed as the best method for developing a policy of optimal conjunction management of the subsystems. The optimization of a field model was completed which included three state and twelve decision variables and a sequential decision process extending over 40 time periods of three-month duration.
(*h*) **Optimization of Conjunctively Managed Surface and Groundwater Resources,** G. Aron, *Water Resour. Ctr. Contrib. No. 129*, Univ. of Calif., June 1969.
Optimization of Conjunctively Managed Surface and Groundwater Resources by Dynamic Programming, G. Aron, *Ph.D. Thesis*, July 1969.

016-07195-840-33

DRAINAGE DESIGN AS INFLUENCED BY CONDITIONS IN THE VICINITY OF THE DRAIN LINE

(*b*) OWRR, Water Resources Center, Univ. of California.
(*c*) Dr. James N. Luthin.
(*e*) Determine exit gradients causing movement of sands and silts into drain pipes for a variety of conditions; determine optimum size of gravel envelope; determine effect of crack width on flow into drain lines; and determine optimum spacing and location of perforations on drain lines.
(*h*) **Some Factors Affecting Flow into Drainpipes,** J. N. Luthin, A. Haig, *Hilgardia* **41,** 10, pp. 235-245, Feb. 1972.

016-07196-200-10

SURGES IN DRY CHANNELS

(*b*) Hydrologic Engrg. Center, U.S. Corps of Engineers; OWRR-WRC, University of California.
(*c*) Dr. Theodor S. Strelkoff.
(*d*) Theoretical, basic and applied; Ph.D. thesis.
(*e*) A general numerical solution is sought for the movement of a water wave down a dry channel of arbitrary cross-section which may be hydraulically rough and pervious. Application to floods following dam break or cloud-burst storms; advance of irrigation water down a furrow or border. Central assumption is hydrostatic pressure distribution, shallow water theory.
(*g*) Preliminary problem of flooding due to rupture of a dam into a valley containing a stream has been solved by the method of characteristics with isolation and tracking of the bore, and by finite-difference continuous computation of integrated continuity and momentum equations. The two methods show good agreement. Flooding following dam rupture in a rough dry bed of wide, rectangular cross-section has also been computed.
(H)[**Computation of Open-Channel Surges and Shocks,** G. Terzidis, T. Strelkoff. *J. Hydraul. Div., Proc. ASCE* **96,** HY12, pp. 2581-2610, Dec. 1970.

016-07197-420-00

SOLITARY WAVES OF CONSTANT FORM

(*c*) Dr. Theodor Strelkoff.
(*d*) Theoretical; basic.
(*e*) The two-dimensional solitary wave is transformed to the steady case by translating the coordinate system at the wave velocity. Potential flow is assumed and the free-surface zero-pressure condition is expressed exactly in terms of an integral of the free-surface elevation, approximately weighted. The result is an integral equation in the surface profile with wave velocity as a parameter set *a priori*. Expression of the integral in quadratures leads to a method of successive approximation for the wave shape. An algorithm was found for determining by successive approximations the limiting, maximum wave height and celerity, as well as the (cusped) wave profile.
(*f*) Completed.
(*g*) Profiles have been obtained for a range of amplitudes 0.1 to 0.85, the maximum possible relative height of the wave.
(*h*) **An Exact Numerical Solution of the Solitary Wave,** T. Strelkoff, *Proc. 2nd Intl. Conf. Numerical Methods in Fluid Dynamics*, Sept. 15-19, 1970, Univ. of Calif., Berkeley. *Lecture Notes in Physics*, No. 8, Springer-Verlag, Berlin, N.Y., pp. 441-446, 1971.

016-07198-810-10

RUNOFF FROM ARID AND SEMIARID CLIMATE WATERSHEDS

(*b*) Dept. of Army, Corps of Engineers.
(*c*) Dr. J. Amorocho.
(*d*) Theoretical and experimental; basic and applied.
(*e*) (1) Studies on the spatial and temporal distribution of convective storm precipitation; (2) development of models for precipitation fields from (1); (3) development of distributed parameter models for small arid watersheds with inputs from (2).
(*g*) A convective storm model has been developed based on Arizona and New Mexico storms. Studies are in progress for the development of the hydrologic model.
(*h*) **Convective Storm Field Simulation for Distributed Catchment Models,** J. Amorocho, D. Morgan, *Proc. IAHS Intl. Symp. Mathematical Models in Hydrology*, Warsaw, Poland, July 1971.

016-07199-820-61

PHYSICAL, ECONOMIC AND ENVIRONMENTAL RELATIONSHIPS IN THE DESIGN OF ARTIFICIAL RECHARGE FACILITIES

(*b*) Water Resources Center, Univ. of California.
(*c*) Dr. Verne Scott, Dept. of Water Science and Engrg.;Dr. Warren E. Johnston, Dept. of Agricultural Economics.
(*d*) Analytical/experimental combined with field work, Ph.D. thesis.
(*e*) Study the rates of infiltration and direction of flow from artificial recharge facilities, such as ponds, canals, trenches, and downwells with particular attention to testing the agreement between laboratory and field observations with current theories on unsaturated flow; determine the effects of various shapes, bank slopes, and geometric

patterns of recharge facilities on groundwater replenishment and economic efficiencies; and determine the design relationships of physical and economic efficiencies to aesthetic attractiveness and environmental usefulness of recharge facilities.

016-07200-210-60

POWER LOSSES IN COMBINING MANIFOLDS

(*b*) Dept. of Water Resources, State of California.
(*c*) Professor J. Amorocho.
(*d*) Theoretical and experimental; basic and applied; Doctoral thesis.
(*e*) Studies of the flow in converging manifolds, taking into account the mechanism of diffusion of turbulent flows. Laboratory studies involving the movement of turbulence, momentum and mass transfer, and energy dissipation in combining manifolds.
(*f*) Completed.
(*g*) Power losses and loss coefficients were determined for a pumping plant discharge manifold with seven branches. A topologic index was developed to characterize all the combinations of branch flows and to determine optimal operating conditions from the standpoint of power losses.
(*h*) **Hydraulic Analysis of the A. D. Edmonston Pumping Plant Manifold,** J. J. DeVries, J. Amorocho, *Water Sci. and Engrg. Paper No. 1032*, Aug. 1969.
Power Losses and Flow Topologies in a Converging Manifold, J. Amorocho, J. J. DeVries. *ASCE J. Hydraul. Div.* **97**,HY1, Jan. 1971.

016-07925-020-61

TURBULENCE IN DIVERGING SHEAR FLOW

(*b*) Water Resources Center, Univ. of California.
(*c*) Professor J. Amorocho.
(*d*) Theoretical and experimental, as tool for design.
(*e*) Detailed study of characteristics of gradually diverging, boundary attached shear flow to obtain information for precise design of expanding transitions and diffusers.
(*f*) Completed.
(*g*) Detailed description of the field of flow of mean energy and turbulence energy throughout the system.
(*h*) **A Study of the Turbulence Characteristics of Diverging Shear Flow,** A. F. Babb, J. Amorocho, *Water Sci. and Engrg. Paper No. 1048*, Dec. 1971.

016-07926-420-00

WAVE DEFORMATION IN WATER OF NONUNIFORM DEPTH

(*c*) Dr. Theodor Strelkoff.
(*d*) Theoretical/basic; Ph.D. thesis.
(*e*) Conformal mapping and complex-variable theory is used to solve two-dimensional unsteady irrotational flows of water with a free surface deforming under the influence of gravity.

016-07927-840-00

COMPUTER MODELS FOR DETERMINING IRRIGATION EFFICIENCIES

(*c*) Dr. Theodor Strelkoff.
(*d*) Theoretical/applied, design, operation.
(*e*) Mathematical models of the surface-irrigation process are constructed by numerically solving the governing partial-differential equation of flow over a porous bed for given design parameters; ground roughness and infiltration characteristics, vegetative density, length and slope of field; also given management option; size of stream, duration, and variation with time. The resulting degree of uniformity of subsurface distribution of water, the wastage in runoff from the end of the field and in deep percolation, and the efficiency of water application are thus determined.
(*g*) Several hypothetical irrigations in borders have been performed, substantiating Criddles' three-fourths rule recommending cut-back in stream size when advance is 3/4 down the field.
(*h*) **Prediction of Increases in Surface-Irrigation Efficiency,** T. Strelkoff, *ASCE Natl. Water Res. Mtg.*, Atlanta, Ga., Jan. 24-28, 1972. Preprint available.

UNIVERSITY OF CALIFORNIA, IRVINE, School of Engineering, Irvine, Calif. 92664. Professor R. R. Brock.

017-07978-820-33

HYDRODYNAMICS OF ARTIFICIAL GROUNDWATER RECHARGE

(*b*) Office of Water Resources Research.
(*d*) Experimental and theoretical research, will include Ph.D. dissertation.
(*e*) A study to develop reliable methods for predicting the hydrodynamic behavior of various artificial groundwater recharge patterns in unconfined aquifers. A sand model, mathematical models and field studies are being employed.

UNIVERSITY OF CALIFORNIA, LOS ANGELES, School of Engineering and Applied Science, Engineering Systems Department, Los Angeles, Calif. 90024. Professor Moshe Rubinstein, Department Chairman.

018-07201-800-00

OPTIMIZATION OF WATER RESOURCES DEVELOPMENT: PHASE II.

(*c*) Professors W. A. Hall and W. W-G. Yeh.
(*d*) Basic and applied research.
(*e*) A comparative evaluation will be made of the use of "critical period hydrologies" to develop optimum operating policies as contrasted to more sophisticated but more expensive analytical procedures. The preceding project has used a critical period of seven dry years (1928-1934), and decisions on firm outputs have been based on this. This will be examined to evaluate the extent to which conclusions based on it depart from those using other methods. It will be evaluated first on simple systems and then later applied to large integrated systems.
(*f*) Completed.
(*h*) **Nonsteady Flow to a Surface Reservoir,** W. W-G. Yeh, *J. Hydraul. Div.*, ASCE **96**, HY3, Proc. Paper 7137, Mar. 1970, pp. 609-618.
A Comparative Study of Critical Drought Simulation, A. J. Askew, W. W-G. Yeh, W. A. Hall, *Water Resour. Res.* **7**, 1, Feb. 1971, pp. 52-62.
Optimal Policy for Reservoir Operation, R. C. Harboe, F. Mobasheri, W. W-G. Yeh, *J. Hydraul. Div.*, *ASCE* **96**, HY11, Nov. 1970, pp. 2297-2308.

018-07202-800-00

OPTIMIZATION OF WATER RESOURCES DEVELOPMENT: PHASE III.

(*c*) Prof. W. W-G. Yeh.
(*d*) Basic and applied research.
(*e*) The objective of the research is the application of operations research techniques to determine the best possible set of components for regional, complex, multipurpose water resources systems. In addition to many alternative schemes for development of regional or river basin water resources, there are many alternative capacity levels which could be specified as a master plan for regional development. Since zero capacity is equivalent to a negative decision with respect to any alternative component, the problem of optimization for regional or river basin planning purposes is equivalent to optimizing the capacities specified for the basin or region master plan. The optimization is subject to the requirements of the many con-

straints that must be imposed, including the hydrological, economic, social, political, and legal constraints, as well as the usual physical limitations. In addition, regional and river basin water plans will involve many specific objectives, some of which are not quantitative or readily relatable with equivalent economic accuracy, but may nonetheless be of critical importance. Any analytical model must permit reconciliation with the objectives if they cannot be explicitly incorporated.

(*h*) **Optimal Planning and Operation of a Multiple Purpose Reservoir System,** W. W-G. Yeh, A. J. Askew, W. A. Hall, *7th Mathematical Symp.*, The Hague, The Netherlands, Sept. 1970.

Optimal Design of a Single Reservoir System with Pump-Back Capability, Y. D. Desai, *M.S. Thesis*, School of Engrg. and Appl. Sci., Dec. 1970.

An Annotated Bibliography on the Design of Water Resources Systems, H. Asfur, W. W-G. Yeh, *Water Resour. Ctr. Contrib. No. 134*, Mar. 1971.

Multi-Level Optimization of a Reservoir System, W. J. Trott, W. W-G. Yeh, *ASCE Natl. Mtg. on Environmental Engrg.*, St. Louis, Mo., Oct. 18-21, 1971; also submitted to *J. Hydraul. Div., ASCE*, 1971.

Optimizing the Operation of a Single Multiple Purpose Reservoir System, W. S. Parker, *M.S. Thesis*, directed by W. W-G. Yeh, School of Engrg. and Appl. Sci., Dec. 1971.

018-07928-820-00

OPTIMAL MANAGEMENT OF LEAKY AQUIFER SYSTEMS

(*c*) Professor W. W-G. Yeh.

(*d*) Basic and applied research.

(*e*) The purpose of this research is to investigate and test the applicability of control theoretic techniques for optimal management of leaky aquifer systems. The hydraulic conductivities as well as the storage coefficient of the system are generally unknown and are to be identified from field pumping data. Identification of the mathematical structures of layered aquifers is an essential prerequisite for efficient management of ground water basins.

(*h*) **Quasilinearization and the Identification of Aquifer Parameters,** W. W-G. Yeh, G. W. Tauxe, *Water Resour. Res.* 7, 2, Apr. 1971, pp. 375-381.

A Proposed Technique for Identification of Unconfined Aquifer Parameters, W. W-G. Yeh, G. W. Tauxe, *J. Hydrology* **12**, 2, Jan. 1971, pp. 117-128.

Optimal Identification of Aquifer Diffusivity Using Quasilinearization, W. W-G. Yeh, G. W. Tauxe, *Water Resour. Res.* 7, 4, Aug. 1971, pp. 955-962.

Optimal Identification of Estuary Parameters Using Quasilinearization, N. Young, W. W-G. Yeh, G. W. Tauxe, *7th Ann. Amer. Water Resour. Conf.*, Washington, D.C., Oct. 25-28, 1971.

018-07929-860-00

PROBABILISTIC MODELS IN THE DESIGN AND OPERATION OF A MULTIPURPOSE RESERVOIR SYSTEM

(*c*) Professors S. Arunkumar and W. W-G. Yeh.

(*d*) Basic and applied research.

(*e*) To develop analytical probabilistic models for the optimal operation and design of water resource systems. Such a model is important especially in view of the stochastic nature of the input hydrology.

UNIVERSITY OF CALIFORNIA, LOS ANGELES, School of Engineering and Applied Science, Mechanics and Structures Department, Los Angeles, Calif. 90024. Dr. Robert E. Kelly.

019-07930-060-54

INTERNAL HYDRAULIC JUMPS

(*b*) National Science Foundation.

(*d*) Theoretical and experimental, basic research (Ph.D. thesis).

(*e*) Investigation of uniqueness of internal hydraulic jumps; comparison of results for a two-fluid model to experiments concerning miscible fluids.

(*g*) The question of non-uniqueness in internal hydraulic jumps can be resolved without solving the initial value problem. Experimental results are obtained which serve to delimit the applicability of the two-fluid model from the viewpoints of interfacial shear and turbulent entrainment.

019-07931-060-54

STABILITY OF BUOYANCY INDUCED FLOWS IN A STRATIFIED FLUID

(*b*) National Science Foundation.

(*d*) Theorctical, basic research; Ph.D. thesis.

(*e*) The stability of flows induced by a heated or cooled inclined surface, with an ambient, quiescent stratified fluid outside the boundary layer, are investigated by numerical methods.

(*g*) The mode of two-dimensional, progressive waves is found to be predominant for all angles of inclination. The thermal convection mode (spanwise rolls) is found to be always more stable.

UNIVERSITY OF CALIFORNIA, SAN DIEGO, Institute of Geophysics and Planetary Physics, La Jolla, Calif. 92037. Dr. Walter Munk, Associate Institute Director.

020-05927-420-20

DEEP SEA TIDES

(*b*) Office of Naval Research.

(*c*) Dr. Walter Munk and Dr. Frank Snodgrass.

(*d*) Field investigation, theoretical analysis, basic research.

(*e*) A self-recording instrument package is dropped freely to the sea bottom and records, *in situ*, pressure, temperature, and currents to a high degree of precision. The instrument is acoustically recalled from a surface vessel, typically after one month.

(*g*) On the basis of a number of stations off California, a part-descriptive, part-analytical description of deep-sea tides for the northeast Pacific and the Antarctic have been developed.

(*h*) **The Benthic Boundary Layer,** M. Wimbush, W. H. Munk, *The Sea* **4**, 1, Ch. 19, ed. by Maxwell, 731-758, 1971.

Tides Off-Shore; Transition From California Coastal to Deep-Sea Waters, W. H. Munk, F. E. Snodgrass, M. Wimbush, *Geophys. Fluid Dynamics* **1**, 1, 161-235, 1970.

Tides of the Deep Sea, W. H. Munk, *Explorers J. XLVIII*, 3, 177-183, 1970.

Tidal Constants Derived From Response Admittances, B. Zetler, D. Cartwright, W. Munk, *6th Intl. Symp. on Earth Tides*, Strasbourg, Sept. 1969, 175-178, 1970.

Tides in Shallow Water; Spectroscopy, B. Gallagher, W. Munk, *Tellus* **23**, 4-5, 346-363, 1971.

M_2 Amphidrome in the Northeast Pacific, J. D. Irish, W. H. Munk, F. E. Snodgrass, *Geophys. Fluid Dynamics* **2**, 355-360, 1971.

ELTANIN Cruise 41, F. E. Snodgrass, *Antarctic J. of the U.S.* **VI**, 1, 12-14, 1971.

020-07932-420-20

ABYSSAL INTERNAL WAVES

(*b*) Office of Naval Research.
(*c*) Dr. Walter Munk and Dr. Frank Snodgrass.
(*d*) Field investigation, theoretical analysis, basic research.
(*e*) A self-recording instrument package is made to be neutrally buoyant at some predetermined depth, and then programmed to undergo slight buoyancy variations which make the instrument yo-yo up and down relative to the mean position. Pressures and temperatures are recorded to very high precision. The instrument is followed acoustically by a surface vessel, and is to be recalled typically after one week.
(*h*) **Internal Wave Spectra in the Presence of Fine-Structure,** C. J. R. Garrett, W. H. Munk, *J. Phys. Oceanog.* **1**, 3, 196-202, 1971.

CARNEGIE-MELLON UNIVERSITY, Department of Chemical Engineering, Pittsburgh, Pa. 15213. Dr. Stephen L. Rosen, Associate Professor.

021-07933-210-00

ENTRANCE LOSSES IN LAMINAR FLOW

(*d*) Experimental, basic research, Ph.D. thesis.
(*e*) When a fluid passes from a large tube into a smaller one, excess pressure losses are observed in the entry region. These excess losses result from friction during velocity profile rearrangement, addition of kinetic energy, and, in the case of visco-elastic fluids, elastic energy storage. Such flows are important in many technological operations. Entrance losses are being investigated for a variety of fluids over a Reynolds number range of 1-2000.
(*g*) Entrance losses are given by $2\Delta P/\rho V^2 = K + K'/Re$ where the coefficients K and K′ are functions of geometry, the fluid's power-law index, n, and its elastic properties. K and K′ increase with n and with fluid elasticity. For Newtonian fluids flowing through a sharp-edged contraction, $K = (2.32 \pm .05)\ (1-\beta^2)$, and $K' = (159 \pm 30)\ (1-\beta^2)$, where β = area contraction ratio.
(*h*) **Laminar Flow in the Entrance Region of a Cylindrical Tube: Part I Newtonian Fluids, Part II Non-Newtonian Fluids,** N. D. Sylvester, S. L. Rosen, *AIChEJ* **16**, 964, 1970.
The Dependence of Laminar Entrance Loss Coefficients on Contraction Ratio for Newtonian Fluids, S. E. Kaye, S. L. Rosen, *AIChEJ* **17**, 1269, 1971.

UNIVERSITY OF CINCINNATI, Department of Chemical and Nuclear Engineering, Cincinnati, Ohio 45221. Dr. J. H. Leonard, Department Head.

023-07227-130-52

BOILING AND TWO-PHASE FLOW STUDIES

(*b*) U. S. Atomic Energy Commission.
(*c*) Dr. Joel Weisman.
(*d*) Experimental and theoretical, basic and applied research, M. S. and Ph.D. theses.
(*e*) Study of flow properties of vapor-liquid mixtures under steady state and transient conditions. Application to water cooled nuclear power reactor during accident conditions.

023-07228-130-00

FOAM DRAINAGE AND OVERFLOW

(*c*) Dr. Robert Lemlich.
(*d*) Experimental and theoretical, basic and applied research, Ph.D. theses.
(*e*) The behavior of liquid foam with regard to its coalescence, interstitial drainage, liquid content, and bulk flow. Applications to foam fractionation, drainage, and flow.
(*h*) **Some Physical Aspects of Foam,** R. Lemlich, *J. Cosmetic Chem.*, in press.
Adsubble Methods, R. Lemlich, in *Recent Developments in Separation Science*, N. L. Li, ed., Chemical Rubber, Cleveland, Ohio, in press.
Separations Based on Bubble Adsorption, R. Lemlich, in *Chem. Engrs. Hdbk.* 5th edition, R. H. Perry, C. H. Chilton, Editors, McGraw-Hill, N.Y., in press.
Adsubble Processes; Foam Fractionation and Bubble Fractionation, R. Lemlich, *J. Geophys. Res.* **77**, 27, pp. 5204-10, 1972.
Adsorptive Bubble Separation Techniques, R. Lemlich, ed. (and also author of pp. 1-5, 33-51, 133-143), Academic Press, N.Y., 1972.
Continuous Foam Drainage and Overflow, F. S. Shih, R. Lemlich, *Ind. Eng. Chem. Fundamentals* **10**, 254-259, 1971.
Foam Fractionation in the Crits Ring Test, R. Lemlich, *J. Colloid Interface Sci.* **37**, 497, 1971.
Foam Fractionation, R. Lemlich, *Videotape, Television Station WCET*, 30-minute, half-inch, color, sound, 1970.

023-07937-150-00

BUBBLE FRACTIONATION

(*c*) Dr. Robert Lemlich.
(*d*) Experimental and theoretical, basic and applied research, M.S. theses.
(*e*) A study of the vertical segregation of components that occurs within a liquid as a result of adsorption at the surfaces of rising bubbles. Possible application to water pollution control and to natural bubble processes in sea and lakes.
(*h*) **A Theoretical Study of Bubble Fractionation,** K. D. Cannon, R. Lemlich, *Chem. Eng. Prog. Symp. Ser.*, in press.
Separation of Dyes in Nonfoaming Adsorptive Bubble Columns, G. N. Shah, R. Lemlich, *Ind. Eng. Chem. Fundamentals* **9**, 350-355, 1970.

023-07938-140-50

BOILING DURING PRESSURE TRANSIENTS

(*b*) National Aeronautics and Space Administration.
(*c*) Dr. Joel Weisman.
(*d*) Experimental and theoretical, basic and applied research, M.S. theses.
(*e*) Study of departure from thermodynamic equilibrium during pressure transients.

UNIVERSITY OF CINCINNATI, Department of Civil and Environmental Engineering, Hydraulic Laboratory, Cincinnati, Ohio 45221. Dr. L. M. Laushey, Head, Civil and Environmental Engineering Department, Dr. H. C. Preul, Directing Head, Hydraulic Laboratory.

024-06462-070-00

UNSTEADY FLOW

(*c*) Dr. Louis M. Laushey.
(*d*) Experimental and theoretical; Doctoral dissertation.
(*e*) Measurements in groundwater tank and Hele-Shaw apparatus to confirm equations for unsteady flow and to determine the friction during unsteady flow.
(*h*) Progress report, *Proc. IASH Symp.*, Bern, Switzerland, Oct. 1967.

024-06464-820-73

MODEL OF GROUNDWATER BASIN

(*b*) Southwestern Ohio Water Company.
(*c*) Dr. Louis M. Laushey and Mr. Robert C. Lewis.

(*d*) Experimental and theoretical.
(*e*) An analog computer solution and a mathematical model have been developed for an aquifer in the Miami River basin. Objective is to develop criteria and methods for the optimum management of the aquifer.
(*h*) Progress report, *Proc. 13th Congr. IAHR*, Paper A54, (Kyoto), Aug.-Sept. 1969.

024-07229-870-36

URBAN RUNOFF CHARACTERISTICS

(*b*) Environmental Protection Agency.
(*c*) Dr. Herbert C. Preul.
(*d*) Theoretical; field measurements; computer modeling.
(*e*) Field data being collected from large urban watershed for development and testing of comprehensive storm water management model.
(*h*) Interim 1st-year report, *EPA Water Poll. Control Res. Series*, 11024 DQU 10/70, Oct. 1970.

024-07934-870-41

TRAVEL OF POLLUTION THROUGH AN AQUIFER

(*b*) U.S. Public Health Service.
(*c*) Dr. Herbert C. Preul.
(*d*) Theoretical; laboratory and field.
(*e*) Measurements for the development of practical methods for the analysis of the transport of pollutants in flow through an aquifer.
(*h*) **Travel of Pollutants Through an Aquifer**, *Proc. Purdue Industrial Waste Conf.*, May 1971.

024-07935-300-36

ESTIMATION OF STREAMFLOW CHARACTERISTICS USING AIRPHOTOS

(*b*) Partly supported by EPA.
(*c*) E. A. Joering and Dr. Herbert C. Preul.
(*d*) Theoretical, laboratory and field.
(*e*) Development of a procedure for estimating a flow duration curve and floods of selected frequency using airphotos.

024-07936-250-00

VISCOELASTIC BOUNDARY HYDRAULICS

(*c*) Dr. Louis M. Laushey.
(*d*) Experimental and theoretical; Ph.D. dissertation.
(*e*) Waves are developed and measured on a layer of gelatin coating the bed of an open channel. The friction loss in the fluid and the dissipation within the gelatin are measured.

CLARKSON COLLEGE OF TECHNOLOGY, Department of Mechanical Engineering, Potsdam, N.Y. 13676. George Leppert, Department Chairman.

025-07939-860-00

A BUOYANCY-DRIVEN DESALINATION UNIT

(*c*) Dr. C.A. Hieber.
(*d*) Theoretical; basic research.
(*e*) An investigation is being made into the effects of concentration-induced buoyancy effects in a horizontal circular pipe at pipe Reynolds numbers corresponding to laminar flow. Preliminary results indicate that, under readily obtainable conditions, the buoyancy effect eventually (i.e., in proceeding along axial direction) dominates in the salt-concentration boundary layer. It is found that such a buoyancy-dominated flow can sustain product rates of 10 gal/day ft^2 while keeping the salt concentration at wall to below twice the inlet bulk concentration.

025-07940-140-00

MIXED THERMAL CONVECTION IN A HORIZONTAL PIPE

(*c*) Dr. C.A. Hieber.
(*d*) Theoretical; basic research related to Ph.D. thesis.
(*e*) An investigation is being made into the effects of buoyancy effects in an isothermally heated, horizontal circular pipe for large Prandtl-number fluids and for pipe Reynolds numbers corresponding to laminar flow. It has been found that in proceeding along axial direction, three distinct regions exist. A near region, in which the thermal boundary layer is governed by forced flow; an intermediate region, in which the temperature field is dominated by natural convection; a far region, in which the buoyancy effect decays as the thermal distribution approaches a final uniform value (that of the wall) via forced convection.

025-07941-000-54

VISCOUS FLOWS AROUND DEFORMING BODIES

(*b*) National Science Foundation.
(*c*) S.P. Lin.
(*d*) Theoretical and experimental, Ph.D. thesis.
(*e*) To study the mass and energy transfer around deforming boundaries.
(*g*) Drag force on a radially deforming sphere in a creeping motion is obtained.
(*h*) *SIAM J. Appl. Math.* **21,** 469, 1971.

CLEMSON UNIVERSITY, Department of Chemical Engineering, Clemson, S.C. 29631. Professor C. E. Littlejohn, Department Head.

026-07942-250-00

TURBULENT DISPERSION IN THE PRESENCE OF DRAG REDUCING ADDITIVES

(*c*) J. P. Peterson, Graduate Student or W. F. Beckwith, Assoc. Professor.
(*d*) Experimental, theoretical, basic; Ph.D. thesis.
(*e*) The objective of this work is to determine the effect of high molecular weight drag reducing additives on the turbulent dispersion coefficient. Tracer concentration profiles in the longitudinal direction will be measured at various stations along the length of a wide open channel. Correlation of the data will be attempted by determining the dependence of the turbulent dispersion coefficient on polymer concentration.

COLORADO SCHOOL OF MINES, Basic Engineering Department, Golden, Colo. 80401. Professor R. R. Faddick.

027-08128-260-34

MINERAL SLURRY DATA BANK

(*b*) U.S. Bureau of Mines.
(*e*) Headloss data from 16 pipeline studies of mineral slurries have been compiled into a computer data bank for studying design velocities and headloss correlations.
(*g*) Two equations have been developed for design velocities. A library of Stanton diagrams has been compiled for the mineral slurries.

027-08129-260-34

COAL-WATER SLURRY PROPERTIES

(*b*) U.S. Bureau of Mines.
(*e*) Pipeline rheograms and true rheograms obtained from rotational viscometers are being compared for different sizes of coal, 100/200 and 200/0 Tyler mesh and mixed sizes.

027-08130-130-00

COARSE SLURRY VISCOMETER

(*b*) Colorado School of Mines Research Committee.
(*d*) Experimental; development.

(*e*) A "viscometer" is being developed to handle mineral slurries coarser than 65 Tyler mesh.

027-08131-130-70

RHEOLOGY OF MINERAL SLURRIES

(*b*) Commercial.
(*d*) Applied research.
(*e*) Rheological data are being measured for mineral slurries such as uranium concentrates, copper tailings, cements, zinc oxide slurries and coal in oil.
(*g*) Most mineral slurries are pseudoplastic.

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COLORADO SCHOOL OF MINES, Department of Geology, Golden, Colo. 80401. Dr. David T. Snow, Associate Professor.

028-07961-490-30

THE HYDRAULIC AND TECTONIC SETTING OF MAN-MADE EARTHQUAKES

(*b*) U.S. Geol. Survey, Natl. Center for Earthquake Research, Menlo Park, Calif..
(*d*) Field investigation, applied research.
(*e*) Geohydrologic and geomorphic history of various sites of reservoirs throughout the world that have triggered earthquakes by filling of a reservoir. Hypotheses that seismicity may develop upon unprecedented reduction in effective stress are being tested.
(*g*) Results inconsistent for Lakes Mead, Kremasta, Bilea, and Monteynard.

028-07962-490-30

ON THE DETERMINATION OF POISSON'S RATIO FOR LARGE FRACTURED ROCK MASSES

(*b*) U.S. Geol. Survey, Natl. Center for Earthquake Research, Menlo Park, Calif..
(*d*) Field sampling and laboratory testing of the deformation properties of single natural fractures in hard rocks, and finite element computer programming of the deformation properties of fractured masses with measured properties as input.
(*e*) The effective magnitude of horizontal stress changes, with given vertical effective stress changes by hydraulic loading, is deduced for large scale fractured rock masses.
(*g*) Preliminary results indicate a linear deformation law for normal stiffness of fractures, and resulting computer studies indicate large changes of horizontal stress in the crust of the earth with vertical changes.

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COLORADO STATE UNIVERSITY, ENGINEERING RESEARCH CENTER, College of Engineering, Foothills Campus, Fort Collins, Colo. 80521. Dr. D. B. Simons, Associate Dean, Engineering Research Center.

030-0096W-860-00

GRAND VALLEY SALINITY CONTROL DEMONSTRATION PROJECT

(*c*) G. V. Skogerboe, Agric. Engrg. Department.
To be published in Water Resour. Res. Catalog.

030-0097W-840-00

HYDRAULICS OF SURFACE IRRIGATION

See Water Resources Research Catalog **4**, 2.0215.

030-0099W-840-33

IMPROVEMENTS IN MOVING SPRINKLER IRRIGATION SYSTEMS FOR CONSERVATION OF WATER

(*b*) Office of Water Resources Research.
(*c*) D. L. Miles, Agric. Engrg. Department.
See Water Resour. Res. Catalog.

030-0150W-810-33

THEORY AND EXPERIMENTS IN PREDICTION OF SMALL WATERSHED RESPONSE, PHASE II.

(*b*) Office of Water Resources Research.
(*c*) E. Schulz.
(*d*) Experimental, theoretical or field investigation. Basic research, applied research, design, operation, development, for thesis or otherwise. See Water Resour. Res. Cat. **6**, 2.0348.

030-0151W-860-33

OPTIMAL WATER QUALITY MANAGEMENT

(*b*) Office of Water Resources Research.
(*c*) G. V. Skogerboe.
This project will be listed in Water Resour. Res. Cat. **7**, as *Institutional Requirements for Optimal Water Quality Management in Arid Urban Lands.*

030-0152W-860-33

WATER QUALITY MANAGEMENT DECISION IN COLORADO

(*b*) Office of Water Resources Research.
(*c*) G. V. Skogerboe.
See Water Resour. Res. Cat. **6**, 5.0244.

030-00055-810-05

SNOW COURSE MEASUREMENTS AND FORECAST ANALYSIS

(*b*) Soil Conservation Service; Colorado Agric. Exp. Station.
(*c*) J. N. Washichek, Snow Survey Supervisor, Agric. Engrg. Section.
(*d*) Field investigations; applied research.
(*e*) Systematic measurements of depth and water content of snow are being made at high elevations in Colorado and New Mexico mountain areas for the purpose of forecasting the runoff of the principal rivers in the interest of irrigation, power, domestic supplies and other uses. Development of remote sensors to provide day by day snow pack analysis. This would provide considerable more data for forecasting as well as evaluation of atmospheric projects and flood potential.
(*g*) Forecasts are now being issued at 44 gaging stations in Colorado and New Mexico. As forecast procedures improve, additional streams will be forecast and other areas of potential power and irrigation development will be investigated on the Colorado, San Juan, Animas and Arkansas Rivers.
(*h*) Colorado Agric. Exp. Sta. General Series Papers Nos. 879, 880, 881, 882 covering monthly snow reports for all of Colorado and New Mexico. Nine small basin reports and one two-state bulletin covering the South Platte River watershed; Arkansas River watershed; Rio Grande watershed in Colorado; Rio Grande watershed in New Mexico; Dolores River watershed; San Juan and Animas River watershed; Gunnison River watershed; Colorado River watershed; Yampa, White and North Platte River watershed; Lower South Platte River watershed. Supplemental reports are issued January 1, May 15, and June 1. Progress reports on the Steamboat Springs Project, San Juan Project in Colorado and Jemez Mountain Project in New Mexico.

030-02885-810-54

HYDROLOGIC STOCHASTIC PROCESS

(See also Nos. 2812 and 2846 in past issues.)
(*b*) National Science Foundation.
(*c*) Dr. V. Yevjevich, Prof. of Civil Engineering.
(*d*) Theoretical, basic research.
(*e*) The studies relate to the stochastic structure of hydrologic time series. Annual, monthly and daily rainfall and runoff data have been studied.

(*g*) Several new statistical methods have been applied to hydrologic time series studies.
(*h*) **Properties of Non-Homogeneous Hydrologic Series,** V. Yevjevich, R. I. Jeng, *Colo. State Univ. Hydrol. Paper No. 32*, Apr. 1969.
Runs of Precipitation Series, J. Llamas, M. M. Siddiqui, *Colo. State Univ. Hydrol. Paper No. 33*, May 1969.
Stochastic Process of Precipitation, P. Todorovic, V. Yevjevich, *Colo. State Univ. Hydrol. Paper No. 35*, Sept. 1969.

030-02911-810-54

LARGE CONTINENTAL DROUGHTS

(*b*) National Science Foundation.
(*c*) V. Yevjevich, Prof. of Civil Engineering.
(*d*) Theoretical; basic and applied research.
(*e*) The purpose of this study is to investigate the physical predictability of droughts, probabilistic properties of droughts of given duration, deficit and areal coverage, and engineering and economic aspects of droughts.

030-05164-700-05

FLOW MEASUREMENT

(*b*) Colorado Agric. Exp. Sta., Civil Engrg. Sect.; Northern Plains Soil and Water Conserv. Res. Div., ARS, U.S. Dept. of Agriculture.
(*c*) Dr. H. J. Koloseus, Prof. of Civil Engineering.
(*d*) Experimental laboratory and basic research which involves staff and graduate student participation leading to M.S. and Ph.D. degrees.
(*e*) This project has the general objectives of developing and improving devices and techniques for the conduction and measurement of irrigation water. At present, the response of stilling wells to pressure fluctuations is being studied.
(*g*) The circular hydraulic jump has been studied analytically and experimentally. The analytical work indicated that the sequent depth and the head loss for the circular jump are greater than that for the rectangular jump. Experiments tended to confirm these findings; they also tended to indicate that the length of the circular jump is less than that of the rectangular jump.
(*h*) **Circular Hydraulic Jump,** H. J. Koloseus, D. Ahmad, *J. Hydraul. Div., ASCE* **95**, HY1, pp. 409-422, Jan. 1969.

030-05892-840-05

FLOW INTO SUBSOIL DRAINS

(*b*) Colo. State Univ. Agric. Exp. Station and Agric. Research Service, U.S. Dept. Agriculture.
(*c*) A. T. Corey, Dept. of Agric. Engrg. and H. R. Duke, ARS, USDA.
(*d*) Experimental, theoretical, applied research and development.
(*e*) Techniques for modeling systems involving drainage from soils are being used to evaluate present criteria for the design of subsoil drains. Both physical and mathematical models are being investigated. Purpose is to develop improved design criteria and in particular, to develop criteria that will take into account flow in the partially saturated region above the water table.
(*g*) A theory of similitude, applicable for models involving drainage from soils, was developed. The models (physical and mathematical) were employed to evaluate the importance (to drainage design calculations) of accounting for flow above the water table. It was shown that satisfactory results cannot be obtained by ignoring this flow. It was also shown that to describe the drainage process mathematically it is necessary to determine the pore-size distribution of the soil.
(*h*) **Permeability Calculated from Desaturation Data,** G. E. Laliberte, R. H. Brooks A. T. Corey, *J. Irrig. and Drain. Div., Proc. ASCE* **94**, IR1, Mar. 1968, pp. 57-71.

030-07001-810-05

SIMULATION OF HYDROLOGIC SYSTEMS

(*b*) Cooperatively with U.S. Dept. Agriculture.
(*c*) Dr. D. A. Woolhiser, Res. Hydraulic Engineer.
(*d*) Theoretical and experimental; basic and applied.
(*e*) Purpose of the project is to develop procedures for numerically simulating the surface runoff hydrograph of small watersheds and to develop objective techniques for transforming complex watersheds into simple combinations of overland flow planes and channels for numerical simulation.
(*g*) Experimental hydrographs from butyl surfaces or gravel-covered surfaces were compared with those predicted by kinematic wave theory. Agreement was good if both laminar and turbulent flow regimes were included in the friction law. The laminar turbulent transition is an important phenomenon in overland flow. If only one resistance law, such as the Chézy is used, errors of plus or minus 20 percent are possible on recession hydrographs. The interaction of infiltration and overland flow has been demonstrated in the kinematic overland flow model in conjunction with the partial differential equations describing vertical porous media flow. The mathematical model was tested by comparison with data from a small experimental watershed.
(*h*) **The Kinematic Cascade as a Hydrologic Model,** D. F. Kibler, D. A. Woolhiser, *Colo. State Univ. Hyd. Paper 39*, Mar. 1970.
Mathematical Simulation of Infiltrating Watersheds, R. E. Smith, *Ph.D. Dissertation*, Colo. State Univ., June 1970.
Overland Flow on Rangeland Watersheds, D. A. Woolhiser, C. L. Hanson, A. R. Kuhlman. *New Zealand J. Hydrol.* **9**, 2, 336-356, Nov. 1970.
Mathematical Simulation of Infiltrating Watersheds, R. E. Smith, D. A. Woolhiser, *Colo. State Univ. Hydrol. Paper 47*, Jan. 1971.
Overland Flow on an Infiltrating Surface, R. E. Smith, D. A. Woolhiser, *Water Resour. Res.* **7**, 4, 899-913, Aug. 1971.
Experimental Investigation of Converging Overland Flow, D. A. Woolhiser, M. E. Holland, G. L. Smith, R. E. Smith, *Trans. ASAE* **14**, 4, 684-687, Jul.-Aug. 1971.

030-07239-810-33

ATMOSPHERIC WATER

(*b*) State of Colorado (used partially as matching funds for OWRR project).
(*c*) Dr. J. Rasmussen, Dept. of Atmospheric Science.
(*d*) Experimental research; applied research.
(*e*) Study of the atmospheric water balance in cyclones, and over river basins. Purpose is to model the evaporation, condensation, precipitation cycle in large extratropical cyclones and relate this to ground responses, e.g., hydrologic phenomena; to use the atmospheric water balance as a computation technique to obtain winter season precipitations minus evaporation over the upper Colorado River and relate this to annual runoff. The benefit of this research would be a forcast equation P - E = f (runoff).
(*g*) An analysis technique for the study of the atmospheric water balance of cyclones has been finished and published.
(*h*) **The Atmospheric Water Balance and Hydrology of Large River Basins,** J. Rasmussen, *Proc. 5th Amer. Water Resour. Conf.*, San Antonio, Tex., Nov. 1969.

030-07241-840-00

IMPROVEMENTS IN MOVING SPRINKLER IRRIGATION SYSTEMS FOR CONSERVATION OF WATER

(*b*) Colo. State Univ. Agric. Exp. Station.
(*c*) D. L. Miles, Agric. Engrg. Department.
(*d*) Experimental and theoretical; applied and basic research development.
(*e*) To investigate the effect of time-varying water application rates on infiltration rates under moving sprinkler systems and to incorporate these findings into mathematical models of moving sprinkler irrigation systems to modify design and operation for improved performance. Present systems apply water in such a manner that it cannot be absorbed uniformly by most soils. Application rates exceed

infiltration rates over a large portion of the irrigated area, resulting in water collecting in low spots. This research will evaluate the infiltration process in the unique conditions found under moving systems and will use the findings to modify equipment to better match application rates to intake rates.

030-07247-800-00

WATER RESOURCES OPTIMIZATION

(*b*) Colo. State Univ., Agric. Exp. Station.
(*c*) E. V. Richardson, Dept. of Civil Engineering.
(*d*) Experimental, theoretical; applied research and development.
(*e*) To research and apply methods to optimization of the water resources of Colorado. Studies include methods of reducing water loss by seepage, evaporation or transportation; to improve efficiency of the distribution systems by consolidation of conveyance systems; application of linear and dynamic programming, and design of conveyance systems.
(*g*) A study was completed on the use of fluorescent dyes for the measurement and tracing of water. A study of ditch consolidation was made. Groundwater quality study was completed.
(*h*) **Dye Dilution Method of Discharge Measurement,** W. S. Liang, E. V. Richardson, Colo. State Univ., Civil Engrg. Dept., 1969.

030-07251-210-70

FIELD TESTING OF WATER PIPELINES

(*b*) Johns-Manville Sales Corporation.
(*c*) M. L. Albertson, Dept. of Civil Engineering.
(*d*) Experimental (laboratory) and field investigation; applied research (design) for Master's thesis.
(*e*) The purpose of this project is to provide information for establishing better procedures for safely and completely testing in place the performance of water pipelines and to explain and describe these procedures adequately for use by the engineer and contractor. Specifically, the following aspects are being investigated: 1) waterhammer resulting from the final stage of air exhaustion from pipelines and the associated rate of pipeline filling, and 2) current and proposed pressure testing procedures and limits.

030-07252-840-56

IMPACT OF TUBEWELLS AS A SOURCE OF IRRIGATION WATER IN THE PUNJAB OF WEST PAKISTAN

(*b*) Agency for International Development.
(*c*) M. L. Albertson, Dept. of Civil Engineering.
(*d*) Theoretical and field investigation; design and development; Ph.D. dissertation.
(*e*) Interdisciplinary mathematical model using field data for optimization of canal water and tubewell water on the farm.
(*f*) Field investigations under way. Initial data in process of analysis.

030-07253-800-56

OPTIMIZATION OF WATER UTILIZATION FOR AGRICULTURAL PRODUCTION

(*b*) Agency for International Development.
(*c*) M. L. Albertson, Dept. of Civil Engineering.
(*d*) Theoretical; Master's thesis; Ph.D. dissertation.
(*e*) The purpose of this study is to determine a mathematical optimizing procedure of water resources development in developing countries with special emphasis on the agricultural aspects of the Indus Basin in West Pakistan and the Pa Mong Project, in the Mekong River Basin of Laos and Thailand.
(*g*) Linear programming solution now being set up.

030-07254-800-56

SYSTEMS ANALYSIS APPLIED TO WATER DEVELOPMENT AND OPERATION

(*b*) Agency for International Development.
(*c*) M. L. Albertson, Dept. of Civil Engineering.
(*d*) Theoretical applied research for Master's thesis and Doctoral dissertation.
(*e*) Application of systems analysis and optimization techniques for the development and operation of West Pakistan water and power resources on a unified and comprehensive basis.
(*g*) Work is in project synthesis stage.

030-07259-810-00

HYDROLOGY OF SMALL WATERSHEDS

(*c*) E. F. Schulz, Assoc. Professor of Civil Engineering.
(*d*) Applied research.
(*e*) A one-acre experimental watershed has been fitted with rainfall simulators. Rainfall can be uniformly applied to the watershed at rates varying from approximately 0.50 to 4.00 inches per hour. The runoff hydrograph is measured in a small H-flume and the rainfall and runoff data are automatically recorded on punched cards.
(*g*) The kinematic wave theory of the formation of a flood hydrograph has been verified.
(*h*) **Design and Testing of Rainfall Systems; Colorado State University Experimental Rainfall-Runoff Facility,** M. E. Holland, *CER 69-70 MEH 21*, Nov. 1969.

030-07260-810-00

FLOODS FROM SMALL WATERSHEDS

(*c*) E. F. Schulz, Assoc. Professor of Civil Engineering.
(*d*) Applied research.
(*e*) Flood hydrographs from small watersheds together with the hyetograph of causal rainfall and pertinent antecedent rainfall and physiography features of the catchment are assembled on magnetic tape. In some instances the frequency of the flood and rainfall are also assembled with the data. The data tapes are then used to provide basic data from natural watersheds for research in the theory of flood synthesis.
(*h*) **Fluvial Physiography as a Factor in Basin Response,** M. Ulugar, *Ph.D. Dissertation*, CSU, June 1969.

030-07264-300-00

WATER RESOURCES HYDRAULICS

(*b*) Colo. State Univ. Exp. Station.
(*d*) Experimental, theoretical; applied research and development.
(*e*) Emphasis has been given to the design and stabilization of canals and rivers and river response to development. Design methods have been developed to stabilize channels considering channel geometry, hydraulics, the properties of bed and bank material, turbulence, seepage, wave forms and other related factors. Similarly, techniques have been developed that help cope with the stabilization of channels at culvert outfalls and for various types of spillthrough structures such as bridge abutments and spur dikes.
(*h*) **Closure, Variation of a and b Values in a Lined Open Channel,** D. B. Simons, F. J. Watts, *J. Hyd. Div., ASCE* **95,** HY3, 1969.
Open Channel Flow, D. B. Simons, Chap. 7, **Channel Flow,** in *Water, Earth, and Man*, ed. R. J. Chorley, Methuen and Co., Ltd. 1969, pp. 297-318. Distributed in U.S. by Barnes and Noble, Inc.

030-07269-820-00

GROUNDWATER RESERVOIR MANAGEMENT

(*b*) Colorado Exp. Station.
(*c*) D. K. Sunada, Assoc. Professor and R. A. Longenbaugh, Asst. Professor.
(*d*) Field studies, theoretical and applied.

(*e*) This project is directed toward developing techniques for efficient groundwater usage.
(*g*) A mathematical model for the prediction of the physical response of water in an aquifer has been refined to include the movement of contaminants. In addition, work on the effects of capillarity (two-phase flow) will be incorporated in the model by June 1970. Another model, showing how the use of water resources may be optimized, was also developed. This model uses the concept of dynamic programming to optimize the size of the development of a system composed of surface reservoirs, artificial recharge facilities, and a groundwater aquifer. Groundwater level measurements for eastern Colorado were measured in Spring 1969 and reported in June 1969. Reports on completed work were sent to State and Federal Agencies in Colorado.
(*h*) **Dispersion in Groundwater Flow Systems,** D. L. Reddell, *Ph.D. Dissertation*, Colo. State Univ., Dec. 1969.
Dynamic Programming in Water Resources, L. Lopez-Garcia, *M.S. Thesis*, Colo. State Univ., Sept. 1969.

030-07943-220-05

SEDIMENT DETACHMENT, TRANSPORT AND DEPOSITION PROCESSES

(*b*) Cooperatively with U.S. Dept. of Agriculture.
(*c*) P. H. Blinco, Hydraulic Engineer.
(*d*) Theoretical and experimental; basic and applied.
(*e*) To determine the probability distribution of the instantaneous boundary shear stress and Reynolds stress near a smooth wall for varying open channel flows and to develop a stochastic model of the sediment detachment and entrainment processes based on turbulent structure in open channel flow.
(*g*) The flume has been instrumented and experimental investigations are about to begin.

030-07944-840-00

SALINITY CONTROL IRRIGATION

(*b*) Colorado Agric. Exp. Station.
(*c*) W. Clyma.
(*d*) Theoretical and field investigation; applied research.
(*e*) To investigate alternate methods of salt balance control on irrigated land which will afford control of the salt load in drainage water.
(*g*) Publications representing the results of work for previous years' work were completed. Plans are being formulated to look at on-farm water management procedures for improving the quality of irrigation return flows. In semi-arid lands good quality groundwater is an important source for irrigation. One major problem is the deterioration of groundwater quality in many areas. The Severance Basin, having poor water quality, was selected as a study to evaluate the causes of quality deterioration. A computer simulation of groundwater in this basin was conducted and it was found that the primary cause of the poor quality water was due to high evapotranspiration. Other sources such as feed lots and oil well brine pits contributed only minor amounts of contaminants.
(*h*) **Numerical Simulation of Dispersion in Groundwater Aquifers,** D. L. Redell, D. K. Sunada, *Hydrol. Paper No. 41*, Colo. State Univ., June 1970.
Numerical Simulation of the Transport Dispersion Equation, D. L. Redell, D. K. Sunada, *Ann. Mtg. Amer. Soc. Agric. Engrs.*, Paper 71-532, June 1971.
Progress Report, Regional Mtg., Kimberly, Idaho, Oct. 1971.

030-07945-810-33

SELECTION OF TEST VARIABLE FOR MINIMAL TIME DETECTION OF BASIN RESPONSE TO NATURAL OR INDUCED CHANGES

(*b*) Office of Water Resources Research.
(*c*) H. J. Morel-Seytoux.
(*d*) Theoretical; applied research; design; thesis.
(*e*) Objective is the optimal selection of a properly weighted combination of hydrologic variables that when tested will detect a hydrologic change in a minimum amount of time.
(*g*) A nonlinear mixed non-negative, free and integer variables programming for stage varying constraints is the technique used for the selection of the variables and the determination of the optimal weights. Results on a realistic case have shown that the methodology works. The methodology has been used to obtain a most efficient test for detection of a change in runoff due to orographic cloud seeding in the Colorado River Basin. The reduction in time for detection at a fixed significance level and power is very appreciable, or of the order of two.
(*h*) **Test of Runoff Increase Due to Precipitation Management for the Colorado River Basin Pilot Project,** H. J. Morel-Seytoux, F. Saheli, *Dept. of Civil Engr., Colo. State Univ. CEP71-72HJM-FS34*, Dec. 1971, 43 pages; also submitted to *J. Appl. Meteorology*.

030-07946-810-33

SYSTEMATIC TREATMENT OF INFILTRATION WITH APPLICATIONS

(*b*) Office of Water Resources Research.
(*c*) H. J. Morel-Seytoux.
(*d*) Experimental, theoretical investigation; basic research; applied research; thesis.
(*e*) Overall objective is to develop a mathematical model of infiltration capable of responding to any spatial and temporal pattern of rainfall or its lack. In this form the model will be readily capable of integration into a general model simulating the hydrologic response of a watershed.
(*g*) The infiltration is treated as a two-phase (water and air) flow phenomenon, as it should. However, this is in fact a new approach to the treatment of infiltration. The research carried up to date has shown that a) effects of air movement and air compressibility on infiltration are important, b) approximate solutions to the right equations give more accurate results than exact solutions to the wrong ones, and c) the approximate solutions are not only more accurate but also more economical.
(*h*) **Analytical Treatment of Two-Phase Infiltration,** R. L. Brustkern, H. J. Morel-Seytoux, *J. Hydraul. Div., ASCE* **96**, HY12, Dec. 1970, pp. 2535-2548.
A Systematic Treatment of the Problem of Infiltration, H. J. Morel-Seytoux, *Completion Rept. Series No. 23*, Environmental Resour. Ctr., Colo. State Univ., June 1971.
Infiltration Prediction by a Moving Strained Coordinates Method, H. J. Morel-Seytoux, A. Noblanc, *Symp. Soil-Water Physics and Technology*, Rehovat, Israel, Aug. 29-Sept. 4, 1971, to appear in Proc. of Conf.
Effect of Soil Air Movement and Compressibility on Infiltration Rates, Le Van Phuc, H. J. Morel-Seytoux, *Proc. Soil Sci. Soc. Amer., Mar.-Apr. 1972.*
A Perturbation Analysis of Two-Phase Infiltration, A. Noblanc, H. J. Morel-Seytoux, *Proc. ASCE* **98**, HY9, Sept. 1972, pp. 1527-41.
Description of Water and Air Movement During Infiltration, R. L. Brustkern, H. J. Morel-Seytoux, *ASCE, J. Hydraul. Division.*

030-07947-810-33

SNOW-AIR INTERACTIONS AND MANAGEMENT OF MOUNTAIN WATERSHED SNOWPACK

(*b*) Office of Water Resources Research.
(*c*) J. Rasmussen.
(*d*) Field investigation and applied research.
(*e*) Project consists of two parts, 1) evaluation of a complete water budget of two alpine watersheds. Included in the budget are precipitation, evaporation (sublimation), snowpack, snow melt, snow drift and runoff, and 2) measurement of evaporation (sublimation) loss from snowpack in forests, clearings and alpine regions. Determination of relationships of evaporation rates to standard climatic data and site characteristics.

(*g*) Project began in July 1971. Presently the watersheds are instrumented and we are analyzing data. The field laboratory setup for the direct measure of sublimation is being built.

(*h*) **Precipitation and Snowpack Data from a High Alpine Watershed,** J. L. Rasmussen, H. S. Santeford, *WMO Symp. on Distribution of Precipitation in Mountainous Areas.*

030-07948-860-36

DATA ACQUISITION SYSTEMS IN WATER QUALITY MANAGEMENT

(*b*) Environmental Protection Agency.
(*c*) R. Ward.
(*d*) Design.
(*e*) The objectives of a state water quality management agency were reviewed and related to the data necessary for them to function properly. Next a design procedure was developed which would provide a water quality monitoring network to match the objectives.
(*g*) Cost-effectiveness curves were developed which related the cost of data acquisition to the effectiveness of the data within the organization. These are to serve as a management tool for water quality management agencies.

030-07949-860-33

METROPOLITAN WATER INTELLIGENCE SYSTEMS, PHASE I

(*b*) Office of Water Resources Research.
(*c*) M. Albertson and G. Smith.
(*d*) Theoretical and field investigation, basic and applied research, for thesis studies and for real world application.
(*e*) The study is a three-phase research program devoted to the establishment of centralized metropolitan water intelligence systems in urbanized and urbanizing areas. By concentrating on needs for data and control capabilities of various systems and combination of systems, the results of this research are directed at the development of control criteria for research, planning, design and operation of urban water resource facilities, and the development of systems analysis techniques for control of such systems.
(*g*) A Real Time Automation Control System (RTACS) model for simulation of automated control of a combined sewer system has been developed for a main line with one intersecting lateral line. The combined sewer system is simulated as a three-reservoir problem only. The use of the RTACS concept to real-world situations is set forth in a series of technical reports. The reports examine the social-political and technological aspects of the implementation of RTACS on a metropolitan area. Phase I completed. Nine technical reports and final report have been prepared on the results of Phase 1 effort. Contact G. L. Smith for reports.

030-07950-840-31

SYSTEMS MANAGEMENT FOR OPTIMUM WATER UTILIZATION

(*b*) U.S. Bureau of Reclamation.
(*c*) W. Hart.
(*d*) Field investigation, design, operation, development, demonstration.
(*e*) Areas which have been dry-land farmed will be placed under irrigation when new project waters being developed by the USBR become available. This project will investigate irrigation systems for use on such lands, with special emphasis on the economics of such systems and the changes in the water characteristics of soils as they go under irrigation. The project funds are sufficient only for demonstration of systems which are currently commercially available.
(*g*) Crops and irrigation systems for the first year of operation of the demonstration farm have been chosen. Equipment is in the process of being ordered.

030-07951-300-15

USE OF REMOTE SENSING TO OBTAIN DATA FOR DESCRIBING THE LARGE RIVER ENVIRONMENT

(*b*) U.S. Army.
(*c*) D. Simons, Assoc. Dean, and M. Skinner, Asst. Professor.
(*d*) Theoretical and field investigation.
(*e*) Particular emphasis is placed on recording and interpreting the phenomena of flow patterns, suspended sediment distribution, surficial sediment deposits and erosion patterns, potential earthslide areas along the banks, vegetation, soil type and moisture content on the flood plain and banks and in the levees, water depth effects, bedform effects, effect of man-made structures on the flow and sedimentation patterns, direct water depth determinations and sediment concentration measurements and the ground ecology of the study reaches. A limited analysis of the ability to use modern analytical photogrammetry techniques pertaining to the shape of certain features will be made.
(*g*) Remote sensing coverage of selected reaches of the Mississippi River in the Vicksburg vicinity using color and color infrared photography, multiband photography and thermal imagery has been obtained and interpreted.
(*h*) Reports may be obtained from Dr. M. M. Skinner.

030-07952-060-54

AN EXTREMAL STUDY OF STRATIFIED SHEAR FLOWS

(*b*) National Science Foundation.
(*c*) E. C. Nickerson.
(*d*) Theoretical, basic research.
(*e*) The goals of the project are to obtain bounds on the turbulent transport of heat and momentum in fully turbulent stratified shear flows, and to examine the effects of small shears on the instability of parallel plate convection.
(*g*) An upper bounding procedure has been formulated and applied to the separate problems of parallel plate convection and plane Couette flow. Numerical solutions have been obtained for the linear instability problem, and we are now looking at finite amplitude disturbances. The project has been in existence for only about six months; however, some preliminary results have been obtained. The predicted effects of a velocity shear on the instability of parallel plate convection are in agreement with other published results.

030-07953-810-54

INVESTIGATION OF WATER RESOURCES IN KARST REGIONS

(*b*) National Science Foundation.
(*c*) V. Yevjevich.
(*d*) Basic and applied research.
(*e*) Various aspects of karst hydrology, quality of karst waters, as well as water resources systems analysis of karst problems are the subject of the project. This is the U.S.A. part of a cooperative research project between Yugoslavia and U.S.A. on karst hydrology and water resources, under PL-480 funds.
(*g*) The research has been initiated in studying the response of karst aquifers with data on precipitation, and runoff of large karst springs. As the research started in December 1971, only the first results are available on the response of karst aquifers.

030-07954-300-13

ENVIRONMENTAL EVALUATION OF THE MISSOURI RIVER NEAR OMAHA, NEBRASKA

(*b*) U.S. Army Engrg. District, Omaha.
(*c*) Dr. M. M. Skinner, Asst. Professor, and Dr. J. F. Ruff, Asst. Professor.
(*d*) Field investigation for applied research.
(*e*) Color infrared and thermal imagery of the Missouri River near Omaha, Nebraska.
(*h*) Progress reports may be obtained from Dr. M. M. Skinner.

030-07955-300-00

FREE MEANDER PATTERN IN INTERMONTANE RIVERS

(*c*) Dr. M. M. Skinner, Asst. Professor.
(*d*) Doctoral thesis.
(*e*) River pattern data from freely meandering stretches of eleven rivers located within the Rocky Mountain region of Colorado, Wyoming, and Montana are presented.
(*f*) Completed.
(*g*) Statistical relationships between mean radius of curvature and average daily discharge, and tortuosity ratio and stream slope are demonstrated. A basic discussion of electromagnetic energy detection and imaging is given and the application of certain remote sensing systems for river pattern identification are described. Color, color infrared, minus blue, and black and white aerial photography, and thermal infrared imagery are evaluated for use in stream pattern definition on the Beaverhead River of Montana. A recommendation is offered for recording the size distribution of cobble-size bed materials. Recommendations are developed for consideration in cases where river pattern alteration or relocation is proposed. A remote sensing system for monitoring the consequence of such river channel changes is given. Some example applications are discussed and recommendations for additional research are noted.
(*h*) **Free Meander Pattern in Intermontane Rivers,** M. M. Skinner, *Doctoral Thesis*, 125, 1971.

030-07956-300-60

PHOTOGRAPHY AND IMAGERY OF BEAVERHEAD RIVER NEAR DILLON, MONTANA

(*b*) Department of Fish and Game.
(*c*) Dr. M. M. Skinner, Asst. Professor, and Dr. J. F. Ruff, Asst. Professor.
(*d*) Field investigation for applied research.
(*e*) Both the environment immediately adjacent to the stream, including vegetative cover, bank conditions, inflow, outflow, and the instream environment, including water temperature, depths, velocities, sediment transport (suspended and bedload), bed material size distribution, and bed forms will be measured or monitored.
(*h*) Progress reports and relative information may be obtained from Dr. M. M. Skinner.

030-07957-810-50

WEATHER WATCH STUDY

(*b*) NASA, George C. Marshall Space Flight Center.
(*c*) Dr. J. F. Ruff, Asst. Professor; Dr. M. M. Skinner, Asst. Professor.
(*d*) Field investigation for applied research.
(*e*) The project demonstrates the applicability of remote sensing and data processing techniques to the use of hydrological simulation models and weather modification studies. The program consists of adopting an existing hydrological submodel to the region involved in the weather modification study being conducted by the Bureau of Reclamation, determining cloud top temperature profiles for application to the weather modification studies, and installing remote sensing instrumentation in the Colorado State University aircraft and collecting flight data on hydrological and meteorological parameters associated with both the weather watch and weather modification studies.
(*h*) Progress reports may be obtained from Dr. J. F. Ruff.

030-07958-840-36

IRRIGATION RETURN FLOW QUALITY LITERATURE ABSTRACTING

(*b*) Environmental Protection Agency.
(*c*) G. V. Skogerboe.
(*d*) Library research.
(*e*) A selected list of 100 publications is being reviewed, with articles pertaining to irrigation return flow quality being abstracted. Abstracts and copies of the articles are being provided to the Water Resources Scientific Information Center (WRSIC) and the Environmental Protection Agency laboratory at Ada, Oklahoma.
(*g*) A research needs report for this subject area has been completed. A report of 1968 and 1969 abstracts will be published during 1972.
(*h*) **Research Needs for Irrigation Return Flow Quality Control,** G. V. Skogerboe, J. P. Law, Jr., *Rept. 13030FVN11/71*, EPA, Washington, D.C., Nov. 1971.

030-07959-860-00

WATER QUALITY MANAGEMENT IN THE SOUTH PLATTE RIVER BASIN

(*b*) Colo. State Univ., Agric. Exp. Station.
(*c*) G. V. Skogerboe.
(*d*) Related to OWRR Project, **Institutional Requirements for Optimal Water Quality Management in Arid Urban Areas,** *Water Res. Research Catalog* **7.**

030-07960-840-00

IRRIGATION PRACTICES, RETURN FLOW SALINITY AND CROP YIELDS

(*b*) Colo. State Univ., Agric. Experiment Station.
(*c*) G. V. Skogerboe.
(*d*) Related to 5.0243, *Water Resources Research Catalog* **6.**

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COLUMBIA UNIVERSITY, Lamont-Doherty Geological Observatory (See Lamont-Doherty Geological Observatory).

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UNIVERSITY OF CONNECTICUT, Marine Sciences Institute, Groton, Conn. 06340. Peter Dehlinger, Institute Director.

031-08004-450-54

COASTAL UPWELLING

(*b*) National Science Foundation, Office for the Intl. Decade of Ocean Exploration.
(*c*) Asst. Prof. R. W. Garvine.
(*d*) Theoretical and field investigations; basic research.
(*e*) Theoretical investigations have been conducted for the steady, wind-driven coastal upwelling of homogeneous water both with and without the effects of bathymetry. A field program is underway that will involve tracking of surface drogues in the Ekman layer during summer upwelling off the Oregon coast.
(*h*) **A Simple Model of Coastal Upwelling Dynamics,** R. W. Garvine, *J. Phys. Oceanog.* **1**, 3, pp. 169-179.
Bathymetric Effects on the Coastal Upwelling of Homogeneous Water, *EOS*, *Trans. Am. Geophys. Un.* **52.**

031-08005-400-44

RIVER DISCHARGE INTO LONG ISLAND SOUND

(*b*) National Oceanic and Atmospheric Administration, Office of Sea Grant Programs.
(*c*) Asst. Prof. R. W. Garvine.
(*d*) Field investigations; applied research.
(*e*) Field investigations of the Connecticut River discharge plume have been initiated in conjunction with a larger program to determine a heavy metal budget for eastern Long Island Sound. Salinity, temperature and water surface color in the discharge area are measured using boats and aircraft. Drogues will be tracked to determine residence times for freshened surface water in the Sound.

031-08006-400-33

AN INVESTIGATION OF TURBIDITY IN ESTUARINE WATERS

(*b*) Office of Water Resour. Research, Dept. of the Interior.
(*c*) Asst. Prof. W. F. Bohlen.
(*d*) Field investigation; basic research.
(*e*) This investigation is examining the relationship between total turbidity and its component parts. These data are being used to develop methods and instrumentation capable of providing long term *in situ* turbidity data in rivers and estuaries.
(*h*) **Turbidity Measurements in Estuaries,** W. F. Bohlen, Abstract, *EOS Trans. Amer. Geophys. Un.* 53, 4, 1972.

031-08007-220-44

SUSPENDED MATERIAL TRANSPORT IN LONG ISLAND SOUND

(*b*) National Oceanic and Atmospheric Administration, Office of Sea Grant Programs.
(*c*) Asst. Prof. W. F. Bohlen.
(*d*) Field investigation; applied reasearch.
(*e*) A knowledge of the relationships governing the concentrations of suspended materials is an essential element of a larger program seeking to establish a heavy metal budget applicable to eastern Long Island Sound. During the first year an extensive field investigation will examine the relationship between suspended load concentrations and the total velocity field in the eastern Sound. Two fixed buoy arrays containing temperature, salinity, velocity and turbidity sensors will be used to complement the monthly turbidity data being obtained at a network of twelve stations. These data will be incorporated directly into the calculation of the heavy metal budget and into the development of quantitative predictive techniques.

031-08008-440-87

WINTER CIRCULATION IN LAKE ONTARIO

(*b*) Canada Center for Inland Waters, Burlington, Ontario.
(*c*) Asst. Prof. D. F. Paskausky.
(*d*) Theoretical investigation; basic research.
(*e*) A prognostic, barotropic, numerical circulation model for Lake Ontario has been developed for use with data from IFYGL.
(*f*) Continuing with Univ. of Connecticut support.
(*g*) Lake Ontario set-up during a storm being calculated.
(*h*) **Winter Circulation in Lake Ontario,** D. F. Paskausky, *Proc. 14th Conf. Great Lakes Res.*, 1971.

031-08009-490-22

PHYSICAL OCEANOGRAPHY OF BLOCK ISLAND SOUND

(*b*) U.S. Naval Unu. ·ater Systems Center, New London, Connecticut.
(*c*) Assoc. Prof. A. J. Nalwalk.
(*d*) Field investigation; basic research.
(*e*) Temperature, salinity, sound velocity, currents and plankton are being monitored at four stations in Block Island Sound near the BIFI range.
(*g*) Reports available from NUSC.
(*h*) **Seasonal Variation in Temperature and Salinity in Block Island Sound,** A. J. Nalwalk, D. F. Paskausky, C. Rathbun, R. Williams, *EOS, Trans. Amer. Geophys. Union* 53, 4.

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UNIVERSITY OF CONNECTICUT, School of Engineering, Storrs, Conn. 06268. Professor C. J. Posey. (Summer address; Rocky Mountain Hydraulic Laboratory, Allenspark, Colo. 80510.)

032-05489-370-60

BOUND-ROCK EROSION PROTECTION FOR HIGHWAY DRAINAGE DITCHES

(*b*) Inst. of Water Resources; State Highway Department.
(*d*) Experimental; applied.
(*e*) Develop application of scientific erosion-protection method to highway ditches. Experiments will provide necessary design data and develop construction methods for low-cost installations.
(*f*) Trial installation on route I-91 under continuing observation; others being planned.
(*g*) Trial installation on route I-91 performing satisfactorily; standard specifications being prepared.

032-05769-220-61

FILTER EROSION PROTECTION

(*b*) Water Resources Institute.
(*d*) Basic research; experimental.
(*e*) To determine whether finest-grained non-cohesive and/or cohesive materials can be protected by Terzaghi-Vicksburg inverted filter.
(*g*) If undermining of erosion protection by leaching out of material from underneath is to be avoided, the layers must meet the Terzaghi-Vicksburg inverted filter specifications. Rapidity of failure is proportional to degree of departure from the specifications. Filter layer that will protect D_{50} = 0.045 mm will protect any finer non-soluble material.
(*h*) **Erosion Prevention Experiments,** C. J. Posey, *Proc. 13th Congr. Intl. Assoc. Hydraul. Res., Kyoto* 2, p. 211, 1969.

032-07271-200-00

CRITICAL-DEPTH VERSUS DISCHARGE RELATIONSHIP FOR COMPOUND CROSS-SECTIONS

(*d*) Experimental and theoretical, basic; Master's thesis.
(*e*) Data have been gathered on depths of flow in a channel of compound section (parts of channel having much different depths) near a free overfall and also where slope changes from steep to mild.
(*f*) Suspended.

032-07272-420-61

EXPERIMENTAL STUDIES OF AIR AND WATER INTERFACIAL INTERACTION

(*b*) Institute of Water Resources.
(*c*) Dr. J. D. Lin, Civil Engrg. Department.
(*d*) Experimental; basic research for Master's and Doctoral theses.
(*e*) Experimental investigation of the interaction mechanics with application to the process of dispersion, mixing and diffusion of surface pollutant under the action of turbulent wind.
(*f*) Completed.
(*g*) Turbulent boundary layer characteristics for wind speeds at 20, 25 and 37 feet per second indicated that the effect of pressure gradient is insignificant. The statistical characteristics of wind-generated waves in terms of power density spectra and significant waves showed a larger energy transfer with pressure gradient than that with zero-pressure gradient. The pressure gradient case also had a larger mean surface slope. The ratio of bottom shear stress to surface shear stress was obtained.
(*h*) **Characteristics of Wind-Waves in a Laboratory Channel With and Without Pressure Gradient,** H.C. Liang, *Ph.D. Dissertation*, Univ. of Conn., under preparation.

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THE COOPER UNION SCHOOL FOR THE ADVANCEMENT OF SCIENCE AND ART, Mechanical Engineering Depart-

ment, 51 Cooper Square, N.Y. 10003. Professor C. W. Tan, Acting Department Head.

033-07994-130-00

MASS TRANSFER OF AEROSOLS WITH AXIAL DIFFUSION IN CHANNEL FLOWS

(*d*) Experimental, theoretical, basic research.
(*e*) Determination of coefficients of diffusion of aerosol particles in gaseous streams; effects of axial diffusion in channel flows; study of formation of aerosol in flight; study of chemical reactions in channel flow.
(*h*) **Mass Transfer of Aerosols with Axial Diffusion in Narrow Rectangular Channels,** C. W. Tan, C. J. Hsu, to be published in *Applied Scientific Research*.
Mass Transfer of Aerosols with Axial Diffusion in Circular Tubes, C. W. Tan, *U.S. Atomic Energy Comm. Health and Safety Lab. Res. Rept. HASL-238*, Oct. 1970.
Mass Transfer of Decaying Products with Axial Diffusion in Cylindrical Tubes, C. W. Tan, C. J. Hsu, *Intl. J. Heat Mass Transfer* **13,** pp. 1887-1905, 1970.
Diffusion of Disintegration Products of Inert Gases in Cylindrical Tubes, C. W. Tan, *Intl. J. Heat Mass Transfer* **12,** pp. 471-478, 1969.
Diffusion of Aerosols in Laminar Flow in a Cylindrical Tube, C. W. Tan, C. J. Hsu, *Aerosol Science* **2,** pp. 117-124, 1971.
Low Peclet Number Mass Transfer in Laminar Flow Through Circular Tubes, C. W. Tan, C. J. Hsu, accepted for publication in *Intl. J. Heat Mass Transfer*, 1972.
Aerosol Penetration through a Parallel-Plate Diffusion Battery, C. W. Tan, J. W. Thomas, accepted for publication in *Aerosol Science*, 1972.

CORNELL AERONAUTICAL LABORATORY, INC., OF CORNELL UNIVERSITY, P.O. Box 235, Buffalo, N.Y. 14221. Robert S. Kelso, President.

034-07276-870-65

BUFFALO RIVER PROJECT

(*b*) City of Buffalo (Grant from Environmental Protection Agency).
(*c*) R. C. Ziegler, Head, Environmental Sci. Sect., Environmental Systems Department.
(*d*) Applied research; laboratory and field.
(*e*) Program included the development and evaluation of equipment and techniques that can be utilized for preventing and eliminating oil pollution in the Buffalo River. An extensive sampling program was conducted to determine the amount, type, and distribution of oils in the river. In support of this sampling effort, a variety of oil sampling techniques were evaluated. Various types of oil skimming and containment devices were also evaluated. A pneumatic barrier system for restraining the flow of surface oil was designed, fabricated, and tested. Instrumentation for detecting oil in sewers was also designed, fabricated, and tested. The oil trapping characteristics of an inverted siphon were evaluated, both in the field and in the laboratory using 1/12 and 1/24 scale models.
(*g*) Development of instruments for detecting oil in sewers. Oil detectors based on electrical conductivity and optical transmittance characteristics of oil and water were tested and shown to be suitable for use in sewers. It was shown that pneumatic barriers can restrain the flow of surface oil in stream currents less than one foot per second. Inverted siphons are nearly 100 percent effective in trapping surface-transported oils in sewers.
(*h*) Four topical reports entitled; *Detection of Oil in Sewers*; *Evaluation of a Pneumatic Barrier for Oil Containment*; *Sampling and Identification of Pollutant Oils in Industrial Water-courses*; and *Inverted Siphons for Oil Trapping*, have been prepared and will be available from the EPA. A summary report and a topical report on oil skimmer evaluation are in preparation. Also, the following papers have been published;
Detection of Oil in Sewers, D. H. Bock, E. H. Eckert, *IEEE Trans. on Geoscience Electronics*, Apr. 1972.
Oil Pollution Control On the Buffalo River, R. L. Frank, *Proc. Joint Conf. on Prevention and Control of Oil Spills*, New York City, Dec. 1969.
Development and Evaluation of a Pneumatic Barrier for Restraining Surface Oil in a River, J. Grace, A. Sowyrda, *J. Water Pollution Control Federation* **24,** 12, pp. 2074-2093, Dec. 1970.

034-07975-870-36

A STUDY OF SOME PROBLEMS ON THE PHYSICAL ASPECTS OF THERMAL POLLUTION

(*b*) Environmental Protection Agency.
(*c*) Dr. G. E. Merritt, Res. Aero. Engr. (experimental), or Dr. R. G. Rehm, Res. Mathematician (theoretical), Aero. Res. Department.
(*d*) Theoretical and experimental; applied research.
(*e*) Some basic problems on the physical aspects of thermal pollution were examined. The mechanisms of formation and maintenance of the characteristic thermal structure of deep, temperate lakes have been investigated along with the effects on the basic thermal structure of discharges of waste heat from electric generating plants. The effect of stratification on mixing coefficients was examined experimentally. Measurements of velocity and temperature across the interface between a layer of warm water flowing over a pool of colder water in a channel were used to obtain the mixing coefficients.
(*f*) Completed.
(*g*) A theoretical description of the stratification cycle of temperate lakes is given in which the interaction between wind-induced turbulence and buoyancy gradients is included explicitly. The theoretical model predicts all the observed features of stratification accurately, including some that have never before been predicted analytically. The analytical framework is also used to predict the effects, on the basic stratification cycle, of discharges at or below the thermocline. In the experiments, it is shown that while the downward transfer of both momentum and heat are severely inhibited at the interface by the stable buoyancy gradients, momentum transfer is inhibited to a lesser degree than heat transfer. The measurements confirm that the vertical thermal diffusivity profile can be expressed in terms of a Richardson number defined by surface conditions, depth and temperature gradient as assumed in the theoretical analysis.
(*h*) **Research on the Physical Aspects of Thermal Pollution,** *Water Pollution Control Res. Series Report No. 16130 DPU 02/71*, 188 p., Feb. 1971.
A Study of Some Problems on the Physical Aspects of Thermal Pollution, T. R. Sundaram, R. G. Rehm, G. Rudinger, G. E. Merritt, *Cornell Aero. Lab. Rept. No. VT-2790-A-1*, June 1970.
Formation and Maintenance of Thermoclines in Temperate Lakes, T. R. Sundaram, R. G. Rehm, *AIAA J.* **9,** 7, pp. 1322-1329, July 1971.
Effects of Thermal Discharges on the Stratification Cycle of Lakes, T. R. Sundaram, R. G. Rehm, *AIAA J.* **10,** 2, pp. 204-210, Feb. 1972.
Thermal and Momentum Diffusivity Measurements in a Turbulent Stratified Flow, G. E. Merritt, G. Rudinger, *AIAA Paper No. 72-80*, AIAA 10th Aerospace Sci. Mtg., San Diego, Calif., Jan. 1972.

034-07976-030-18

WAKE LABORATORY EXPERIMENT

(*b*) Advanced Research Projects Agency.
(*c*) Dr. G. E. Merritt, Res. Aerodynamicist, Aero. Res. Department.
(*d*) Analytical and experimental; applied research.

(*e*) To obtain analytical and experimental data that can be used for predicting the concentration (as a function of downstream distance) of a passive tracer released into the wake of a self-propelled body travelling through a stably-stratified medium. To achieve this capability, information is required on the wake shape and size. The experimental approach utilizes a stratified flow in which a composite grid is oscillated to produce a steady-state counterpart of the momentumless wake of a self-propelled body. A pH sensitive indicator in which local color changes are generated at the grid by electrical impulses is used for direct observation of the wake development, diffusion and subsequent vertical collapse as the stable stratification counteracts the wake turbulence.
(*g*) The wake growth before and after collapse and the distance to collapse have been correlated using power laws previously applied for the wakes of re-entry vehicles and a theoretical analysis of marine wake collapse developed under the present program. The theory is based on the balance between the potential energy of the mixed fluid and the energy of the turbulent velocity fluctuations in the wake. Experimental data available from the literature, as well as that obtained in the present program, have been used in the correlation. Although enhancement of the horizontal wake growth due to vertical collapse has been observed, the area of the wake is considerably less than that for unstratified flow.
(*h*) Progress reports are available through request to the sponsor.

034-07977-030-00

A STUDY OF TURBULENT WAKES IN A STRATIFIED FLUID

(*c*) Dr. R. G. Rehm, Res. Mathematician, Aero. Res. Department.
(*d*) Experimental; applied research.
(*e*) The phenomena associated with the two-dimensional, time-dependent growth and collapse of a turbulent region in a density-stratified medium were examined. The results of these experiments are of interest in the study of the turbulent wake produced by a self-propelled body in a stratified fluid.
(*f*) Completed.
(*g*) As part of this study, a technique for producing a quiescent, density-stratified fluid was developed for a tank and flow system previously used to study moving stratified flows. The technique of flow visualization, previously used, was adapted to the present experiments, and a new technique for producing a turbulently mixed region was developed. This latter technique shows additional flexibility over previous techniques used for this purpose. Measurements of features of growth and collapse of the turbulent region compare favorably with previously reported results on turbulent wake collapse.
(*h*) **Turbulent Wakes in a Stratified Medium,** T. R. Sundaram, J. Stratton, R. G. Rehm, *Cornell Aero. Lab. Rept. No. AG-3018-A-1*, Nov. 1971.

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UNIVERSITY OF DELAWARE, Department of Civil Engineering, Newark, Del. 19711. Dr. Eugene Chesson, Jr. Chairman.

035-05047-430-20

BREAKWATER STUDIES

(*b*) Ocean Themis Project, Office of Naval Research, Dept. of the Navy.
(*c*) Dr. K. P. H. Frey, Professor Emeritus.
(*d*) Experimental development; transition period during which more adequate wave studies can be facilitated through the Department.
(*e*) Attempt of developing nearshore breakwaters based on concepts of flow redistribution applied to the specific time-dependent wave flow characteristics with an eye on economical design and construction concepts of the following types. Building block concepts are of interest for single and multiple devices of the stationary, semi-stationary, or floating-moored types. Attenuation must be judged especially in conjunction with the longest design wave length, with the chord length needed for that wave length, and with forces exerted by the waves on the breakwater. The experimental feasibility studies were to be facilitated mostly in a small wave tank of the reporting laboratory, and for one selected model in the 85 ft. long, 6 ft. wide, 4 ft. deep wave-tow tank of the Naval Academy in Annapolis, Md.
(*f*) The expired project is continued with the modest support of the Department of Civil Engineering.
(*g*) Because of encouraging results and the fact that present data are inadequate to the designer for full-scale applications to specific cases, the attempt is being made to choose one such specific case and to follow it up to a full-scale field test in the hope that financial support may be obtained.
(*h*) A final report has just been submitted to Dr. W. S. Gaither, Dean of the College of Marine Studies and Coordinator of the Ocean Themis Project, for submission to the sponsoring agency.

035-06371-290-00

STUDIES ON MECHANICS OF FLUID FLOW

(*b*) Laboratory project in evaluation of sponsored research.
(*c*) Dr. K. P. H. Frey, Professor Emeritus.
(*d*) Experimental; review and outlook.
(*e*) Accessories and instrumentation of the 4,000 gpm flume were adjusted to conduct adequate studies on mechanics of fluid flow in conjunction with technical applications with emphasis on economical approaches and stimulation of creative activity. Most of the several years' work was funded by the U.S. Navy Department, the U.S. Army Materiel Command, and the U.S. Department of Defense in order to carry out specific research work in the areas of amphibious vehicles, breakwaters, fluidics, and problems of detached flow and control.
(*f*) Completed within the requirements of thesis.
(*g*) It appears to be feasible to adjust flume research including future needs of studies on mechanics of fluid flow in conjunction with technical needs for applications.
(*h*) **Flume Research, Theory and Practice,** H. G. Doetsch, *Master's Thesis*, June 1972. Copy of thesis in Morris Library, Univ. of Delaware.

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UNIVERSITY OF DETROIT, College of Engineering, Civil Engineering Department, 4001 W. McNichols Road, Detroit, Mich. 48221. Dr. Eugene Kordyban, Associate Professor.

036-07979-130-54

INVESTIGATION OF THE MECHANISM OF SLUG FORMATION IN TWO-PHASE HORIZONTAL FLOW

(*b*) National Science Foundation.
(*d*) Experimental and theoretical basic research.
(*e*) Basic nature of wavy and stratified air-water flow is being studied theoretically and experimentally to determine the conditions under which the slugs will form.
(*g*) It has been proposed that the slugs form due to the instability of waves which results from low aerodynamic pressure at wave crest. At present, the aerodynamic pressure and gas velocity at the wave surface are being investigated. Special instrumentation, such as liquid level transducer and submersible pressure probe, have been developed.
(*h*) **Mechanism of Slug Formation in Two-Phase Horizontal Flow,** E. S. Kordyban, T. Ranov, *J. Basic Engrg., ASME Trans.* **92,** Series D, p. 257, 1970.
A Method for Measuring Aerodynamic Pressure Below Wave Crests, E. Kordyban, *ASME Paper No. 71-WA/FE-6*, to be published in *Trans. ASME.*

DOUGLAS AIRCRAFT COMPANY, McDONNELL DOUGLAS CORPORATION, Aerodynamics Research, 3855 Lakewood Boulevard, Long Beach, Calif. 90801. W. T. Dickinson, Vice President, Research and Technology.

037-06548-040-22

CALCULATION OF POTENTIAL FLOW ABOUT ARBITRARY CONFIGURATIONS

(*b*) Naval Air Systems Command.
(*c*) J. L. Hess, Chief, Basic Research Group.
(*d*) Theoretical applied research.
(*e*) Develop methods for calculating incompressible flow with no geometrical restrictions on the flow boundaries. Underlying method is based on an integral equation for source density distribution on boundary surfaces. Effort directed towards working computer programs that reduce the integral equation to a matrix equation and solve it. Separate programs exist for different types of geometry–two-dimensional, axisymmetric, and three-dimensional–and for different flow conditions. Presently lift can be accounted for only in two dimensions.
(*g*) The three-dimensional potential flow calculation with lift has been programmed and is being evaluated.
(*h*) **Calculation of Potential Flow about Arbitrary Three-Dimensional Lifting Bodies. Phase I. Final Report,** J. L. Hess, *McDonnell Douglas Rept. No. MDC-JO545*, Dec. 1969.
Calculation of Potential Flow about Arbitrary Three-Dimensional Lifting Bodies. Phase II. Final Report, J. L. Hess, *McDonnell Douglas Rept. No. MDC-JO971/01*, Oct. 1970.
Recent Progress in the Calculation of Potential Flows, A.M.O. Smith, *7th Symp. Naval Hydrodynamics*, DR-148 Office of Naval Research.
Determination of Low Speed Interference Effects by Superposition, J. L. Hess, S. M. Faulkner, *AGARD Conf. Proc. No. 71* on *Aerodynamic Interference*, Sept. 1970.

037-07287-010-00

BOUNDARY-LAYER STABILITY AND TRANSITION

(*c*) A.M.O. Smith, Chief Aerodynamic Engr. for Research.
(*d*) Theoretical applied research.
(*e*) Stability characteristics of incompressible laminar boundary layers on two-dimensional or axisymmetric bodies are obtained from solutions to the Orr-Sommerfeld equation. Studies are in progress attempting to correlate the amplification of disturbances with the experimentally observed location of transition for flows having very low free-stream turbulence levels. The purpose of the investigation is to ascertain whether or not classical linearized stability theory can be used as a tool to predict transition.
(*f*) Suspended.
(*g*) For a number of flows studied, it has been found that the value of the ratio of the disturbance amplitude at transition to its value at the location of neutral stability for the frequency producing the maximum amplification ratio is of the order of e^{10}.
(*h*) **The Determination of Spatial Amplification Factors and Their Application to Predicting Transition,** N. A. Jaffe, T. T. Okamura, A.M.O. Smith, *AIAA J.* **8,** 2, Feb. 1970.
Application of Quasi-Linearization and Chebyshev Series to the Numerical Analysis of the Laminar Boundary Layer Equation, N. A. Jaffe, J. Thomas, *AIAA J.* **8,** 3, pp. 483-49pp. 483-490, Mar. 1970.
A Method for Calculating Laminar Boundary-Layer Profiles and Their Spatial Stability Properties for Two-Dimensional or Axisymmetric Bodies, T. T. Okamura, *McDonnell Douglas Rept. MDC JOO97*, Dec. 1971.

037-07290-540-00

OPTIMIZATION OF AIRFOILS FOR MAXIMUM LIFT

(*c*) Dr. R. H. Liebeck, Sr. Engineer/Scientist.
(*d*) Theoretical applied research.
(*e*) The pressure distribution which provides the maximum lift without separation for monoelement airfoil in an incompressible flow has been determined using existing boundary-layer theory and the calculus of variations. The airfoil profiles corresponding to these pressure distributions have been determined using exact inverse airfoil theory.
(*g*) Results indicate maximum lift coefficients as high as 3.0 for Reynolds numbers between five and ten million. Initial experimental results for an airfoil designed to operate at 2.0×10^6 Reynolds number exceeded theoretically predicted performance and exhibited a low drag "bucket" ($C_D = 0.009$) from $C_L = 0.8$ to $C_L = 2.2$ with very stable and repeatable flow conditions.
(*h*) **Optimization of Airfoils for Maximum Lift,** R. H. Liebeck, A. I. Ormsbee, *AIAA J. Aircraft* **7,** No. 5, Sept.-Oct. 1970.
A Class of Airfoils Designed for High Lift Without Separation in Incompressible Flow, R. H. Liebeck, A.M.O. Smith, *McDonnell Douglas Rept. No.* **MDC J1097/01,** Dec. 1971.
A Wind Tunnel Test of a Laminar Rooftop Airfoil Designed for High Lift Without Separation in Incompressible Flow, R. H. Liebeck, *McDonnell Douglas Rept. No. MDC J5548/01*, Apr. 1972.

037-08580-610-00

CAVITATION EROSION RESISTANCE OF HYDRAULIC METERING VALVES IN PHOSPHATE ESTER HIGH-PRESSURE HYDRAULIC SYSTEMS

(*c*) R. L. Franzen, Sr. Engineer/Scientist.
(*d*) Experimental applied research.
(*e*) A small-scale 3000 psi-rated closed center aircraft hydraulic system is operated in the laboratory to duplicate a wear inducing condition affecting lap fit spool-type metering valves as are typically used in modern commercial aircraft. Response requirements for aircraft surface controls dictate that a minimum dynamic seal area, termed overlap, be employed in the design. Thus, even small configuration changes due to wear grossly affect system response and efficiency. Fluid media employed to date are phosphate ester base fire resistant synthetics. By varying material and configuration design parameters of valves, wear rates are determined. Intent of testing is to learn more about the wear pattern as it varies with the above parameters and with operating time; thus, advance the state-of-art of the aircraft hydraulic system design.
(*g*) Duplication of wear pattern which occurs in aircraft service has been successfully reproduced in laboratory. Mechanism of wear is thought to be combination of cavitation, erosion, and corrosion. Effective system filtration (5 micron nominal) is thought to control erosive contribution to wear to a small portion of total. Neutralization potential (pH) is effectively maintained throughout service; therefore, corrosion is also thought to be a small contributor. Characteristic cavitation type damage has been observed under microscope. Resistance to wear apparently varies with hardness in steel parts, provided that an undefined minimum degree of toughness is present. It is preliminarily indicated that other qualities of the valve material such as cleanliness, homogeneity, and fine grain are important. Final metal removal and processing of the surfaces to achieve a superior finish is also noted to be a significant contributor to wear resistance.

037-08581-040-20

ANALYTICAL INVESTIGATION OF TWO-ELEMENT AIRFOIL SYSTEMS

(*b*) Office of Naval Research.
(*c*) R. M. James, Sr. Engineer/Scientist.
(*d*) Theoretical applied research.
(*e*) Study focuses on the inverse problem of designing two airfoil high-lift systems using the methods of conformal mapping to generate solutions and develop workable design methods.
(*g*) A general mapping theory has been developed and documented for use on IBM computer graphic equipment.

037-08582-540-20

DEVELOPMENT OF POWER PROFILES

(*b*) Office of Naval Research.
(*c*) Dr. A. B. Bauer, Sr. Engineer/Scientist.
(*d*) Theoretical and experimental research.
(*e*) A new concept airfoil is being investigated which is designed to utilize jet propulsion and is dependent upon power to replace streamlining. Analytical studies are to be verified with an experimental investigation.
(*g*) Analytical studies have provided the basic data for design of power profiles for testing.
(*h*) **A New Family of Airfoils Based on the Jet-Flap Principle,** A. B. Bauer, *McDonnell Douglas Report* (to be published).

037-08583-540-26

AERODYNAMICS OF SLAT-AIRFOIL COMBINATIONS

(*b*) Air Force Office of Scientific Research.
(*c*) Dr. R. H. Liebeck, Sr. Engineer/Scientist.
(*d*) Theoretical applied research.
(*e*) Investigation of methods for analysis and design of a leading edge slat plus airfoil. Three basic methods were used, representing the slat as a point vortex, representing the slat as a set of this airfoil singularity distributions, and exact solution of the two element airfoil problem.
(*f*) Completed.
(*g*) A computer program, using the second basic method, was developed to compute the slat camber for a given slat thickness distribution that provides a specified velocity modulation on the nose region of an elliptical main airfoil.
(*h*) **Theoretical Studies on the Aerodynamics of Slat-Airfoil Combinations,** R. H. Liebeck, *McDonnell Douglas Rept. No. MDC J5195*, May 1971.

A General Class of Airfoils Conformally Mapped from a Circle, R. M. James, *McDonnell Douglas Rept. No. MDC J5108*, May 1971.

A Simple Model for the Theoretical Study of Slat-Airfoil Combinations, R. H. Liebeck, D. N. Smyth, *AIAA Paper No. 72-221*, Jan. 1972.

037-08584-040-22

CALCULATION OF POTENTIAL FLOW ABOUT A RING WING WITH TRAILING VORTEX WAKE

(*b*) Naval Undersea Research and Development Center.
(*c*) J. L. Hess, Chief, Basic Research Group.
(*d*) Theoretical applied research.
(*e*) Application of the Douglas-Neumann potential flow program to the problem of calculating flow about a finite propeller shroud or ring wing with energy addition.
(*f*) Completed.
(*g*) Results of this work permit calculation of flow about a ring wing having bound circulation and a trailing ring-vortex wake.
(*h*) **Extension of the Douglas Neumann Axisymmetrical Potential Flow Program to the Problem of a Ring Wing Having a Known Ring-Vortex Wake Issuing from Its Trailing Edge,** J. L. Hess, C. Schoor, *McDonnell Douglas Rept. No.* **MDC JO741/01,** Apr. 1970.

037-08585-000-00

FUNDAMENTAL AERODYNAMIC ANALYSIS

(*c*) A.M.O. Smith, Chief Aerodynamics Engr. for Research.
(*d*) Basic theoretical research.
(*e*) Develop and improve fundamental analysis and calculation techniques for determining fluid dynamic flow properties of internal and external shapes. The aim is greater efficiency and effectiveness of analytical methods in the aircraft design process.
(*g*) Extensive capability in solving three-dimensional potential flows and two-dimensional turbulent boundary layers has been attained. Computation of transitional region, low Reynolds number flow and surface curvature effects are included in the basic boundary layer method. These methods have been applied to comprehensive airfoil optimization for special purposes.
(*h*) **Recent Progress in the Calculation of Turbulent Boundary Layers,** T. Cebeci, A.M.O. Smith, *8th U.S. Navy Symp.*, Corona, Calif., May 1969.

Calculation of Compressible Adiabatic Turbulent Boundary Layers, T. Cebeci, A.M.O. Smith, G. Mosinskis, *AIAA J.* **8,** 11, Nov. 1970.

Calculation of Heat and Mass Transfer in Turbulent Flows at Low Mach Numbers, T. Cebeci, G. J. Mosinskis, *McDonnell Douglas Rept. DAC 70015*, Oct. 1969.

A Decade of Boundary-Layer Research, A.M.O. Smith, *Appl. Mech. Rev.* **23,** 1, Jan. 1970.

Solution of the Incompressible Turbulent Boundary Layer Equations with Heat Transfer, T. Cebeci, A.M.O. Smith, G. Mosinskis, *J. Heat Transfer*, pp. 133-143, Feb. 1970.

Potential Flow and Boundary Layer Theory as Design Tools in Aerodynamics, A. B. Bauer, A.M.O. Smith, J. L. Hess, *Canadian Aeronautics and Space J.* **16,** 2, pp. 53-69, Feb. 1970.

Airfoils Designed Especially for Propulsion Using Boundary Layer Air as the Working Medium, A.M.O. Smith, *McDonnell Douglas Rept. No.* **MDC JO637,** Feb. 1970.

Numerical Solutions of Laminar Boundary Layers, A.M.O. Smith, *AGARD Conf. Proc.* No. 60-70, pp. 56-59.

A Model for Eddy-Conductivity and Turbulent Prandtl Number, T. Cebeci, *McDonnell Douglas Rept. No. MDC-JO747/01 (AD881131)*, May 1970.

Laminar and Turbulent Incompressible Boundary Layers on Slender Bodies of Revolution in Axial Flow, T. Cebeci, *J. Basic Engrg., Trans. ASME*, Sept. 1970.

A Finite-Difference Method for Calculating Compressible Laminar and Turbulent Boundary Layers, T. Cebeci, A.M.O. Smith, *J. of Basic Engrg., Trans. ASME*, Sept. 1970.

Body of Revolution Drag Measurement Results, A. B. Bauer, *McDonnell Douglas Rept. No. MDC-J5167/01*, Dec. 1970.

Behavior of Turbulent Flow Near a Porous Wall with Pressure Gradient, T. Cebeci, *AIAA J.* **8,** 12, pp. 2152-2156, Dec. 1970.

The Laminar Boundary Layer with Uniform Injection of a Foreign Gas, N. A. Jaffe, *Proc. Royal Soc. London A.317*, pp. 393-405, 1970.

Accurate Numerical Methods for Boundary Layer Flows-II. Two-Dimensional Turbulent Flows, H. B. Keller, T. Cebeci, *AIAA Paper No. 71-164*, Jan. 1971.

Investigation and Calculation of Certain New Airfoils Mapped from a Circle, R. M. James, *McDonnell Douglas Rept. No. MDC J5107*, May 1971.

A General Class of Airfoils Conformally Mapped from a Circle, R. M. James, *McDonnell Douglas Rept. No. MDC J5108*, May 1971.

A New Look at Two-Dimensional Incompressible Airfoil Theory, R. M. James, *McDonnell Douglas Rept. No. MDC JO918/01*, May 1971.

Calculation of Compressible Turbulent Boundary Layers with Heat and Mass Transfer, T. Cebeci, *AIAA J.* **9,** 6, pp. 1091-1097, June 1971.

Calculation of Incompressible Turbulent Boundary Layers with Mass Transfer, *J. Heat Transfer, Trans. ASME*, Aug. 1971.

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DREXEL UNIVERSITY, Soil, Water and Urban Engineering, Philadelphia, Pa. 19104. Dr. A. A. Fingaroli.

038-07291-870-36

POLLUTION OF SUBSURFACE WATER BY SANITARY LANDFILL

(*b*) Solid Waste Management Program, Office of Research and Monitoring, Environmental Protection Agency.
(*d*) Experimental, theoretical and field investigation; applied research.
(*e*) Comprehensive long-range objectives are to provide means for predicting the movement of pollutants in subsurface water from existing and proposed sanitary landfills; to develop hydrologic, geologic and soil criteria for the evaluation of site suitability for sanitary landfilling operations, and to appraise design methods and remedial procedures for reducing any undesirable contaminant movement that the study may disclose.
(*g*) A moisture routing model has been completed. The chemical composition of leachate from landfills has been developed. The experimental data is being used to develop soil ion-exchange data and groundwater pollution models.
(*h*) **Instrumentation of Two Experimental Sanitary Landfills,** A. A. Fingaroli, *IEEE Trans. Geoscience Electronics* **Ge-8,** 3, July 1970.
Laboratory Study of the Behavior of a Sanitary Landfill, A. A. Fungaroli, R. L. Steiner, *J. Water Poll. Cont. Fed.*, Feb. 1971.
Criteria for Sanitary Landfill Development, A. A. Fungaroli, R. L. Steiner, *Public Works* **102,** 3, Mar. 1971.
Incinerator-Residue-Fill Site Investigation, R. J. Schoenberger, A. A. Fungaroli, *J. Soil Mech. and Found. Div., ASCE* **97,** 10, Oct. 1971.

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THE FRANKLIN INSTITUTE RESEARCH LABORATORIES, Mechanical and Nuclear Engineering Department, The Benjamin Franklin Parkway, Philadelphia, Pa. 19103. W. H. Steigelmann, Manager, Heat and Fluid Mechanics.

040-07820-340-00

FLOW MODELING STUDIES FOR WATER-COOLED REACTORS

(*d*) Experimental.
(*e*) Several flow model studies have been made using pressurized carbon dioxide to simulate the flow of pressurized water. The use of pressurized carbon dioxide permits high Reynolds numbers to be attained because of the unusually low kinematic viscosity of this fluid. An incidental advantage is that the required pressures are obtained by charging the supply tanks with dry ice, so that compressors are not needed as part of the facility. Measurements made with the CO_2 flow model include flow distribution, pressure distribution, and mixing. Flows are generally measured by sensing the pressure drops across orifices that simulate the hydraulic resistance of flow passages. Flow patterns in other regions have also been studied by injecting cooled carbon dioxide at suitable inlet points and measuring the temperature distribution at downstream points by means of sensitive thermistor elements. The differential pressure and temperature data are recorded automatically on punched cards which provide the input information for a computer program that automatically analyzes and processes the data.

040-07821-340-00

FLOW MODELING STUDIES FOR SODIUM-COOLED REACTORS

(*d*) Experimental.
(*e*) In one nuclear reactor flow modeling study, the upper plenum coolant flow was modeled using water as the modeling fluid. Injection of an electrolyte into the water simulated the sudden drop in reactor core outlet temperature following a shut-down. By measuring electrical conductivity as a function of time near the model outlet, data were obtained from which the thermal shock to the outlet nozzle could be inferred. Another flow model was used to study the core flow distribution in the EBR-II reactor. Water was used in this model, also, permitting the free surface of the coolant in the upper plenum to be simulated. The influence of the proximity of the flow passages upon the effective pressure available to the sideward-facing entrance holes was inferred from flow distribution measurements, permitting adjustment of the hole sizes to yield the desired flows.

040-07822-000-00

DYNAMICS OF ROTATING FLUIDS

(*e*) Oscillation of the free surface of a rotating fluid contained in a cylindrical cavity was investigated. The fluid was assumed to be rotating initially with a Couette-type velocity distribution in a stable configuration. The effects of fill ratio and the initial velocity profile on the frequencies of the subsequent motion were established. The results were of interest in the study of the exterior ballistics of spin-stabilized shells containing non-solid fillers.

040-07823-000-00

VISCOUS FLOW WITH MOVING BOUNDARY AND FREE SURFACE

(*d*) Theoretical.
(*e*) The practical problem of transporting a lubricating oil by means of a partially immersed rotating wheel led to the development of the theory of viscous streamline flow on a vertical upward-moving surface in the presence of a gravitational field when there is a free surface. The approach used was to equate the shear stress at a point in the liquid, due to the weight of liquid at large distances from the moving solid boundary, to the product of viscosity and velocity gradient. The range of possible values for the thickness of the liquid layer was then determined by the condition that the velocity at the free surface is between zero and the value for which total transport of liquid is a maximum. The rate of transport of liquid was found by integrating the resulting velocity distribution.

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GENERAL DYNAMICS CORPORATION, ELECTRIC BOAT DIVISION, Eastern Point Road, Groton, Conn. 06340. V. T. Boatwright, Jr., Manager, Research and Development.

041-07987-060-33

FREE SURFACE EFFECTS ON A BUOYANT JET

(*b*) Office of Water Resources Research.
(*c*) Dr. R. F. Robideau, Research Specialist.
(*d*) Theoretical research with practical applications.
(*e*) Study of the interaction of a turbulent buoyant jet with a free surface. The goal is to predict the maximum surface temperature resulting from the discharge of hot water into receiving water of finite depth. Results will be obtained in dimensionless form in terms of water depth, discharge angle, and Froude number.

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GENERAL ELECTRIC COMPANY, Corporate Research and Development, Mechanical Engineering Laboratory, P.O.

Box 8, Schenectady, N.Y. 12301. Dr. A. M. Bueche, Vice President, Corporate Research and Development.

042-06379-250-00

POLYMERIC FRICTION REDUCTION PROGRAM

(*c*) W. B. Giles.
(*d*) Experimental and analytical investigation.
(*e*) Study of the boundary layer flow of laminar, transition, and turbulent flows with homogeneous and injected friction-reducing additives.
(*f*) Suspended.
(*h*) **Similarity Laws of Friction-Reduced Flows,** W. B. Giles, *J. Hydronautics* **2,** 1, Jan. 1968.

GENERAL ELECTRIC COMPANY, Environmental Sciences Laboratory, P.O. Box 8555, Philadelphia, Pa. 19101. Sinclaire M. Scala, Manager, Environmental Sciences Laboratory.

043-07989-270-50

STUDIES OF PULMONARY BLOOD FLOW DYNAMICS

(*b*) NASA Headquarters.
(*c*) Dr. N. R. Kuchar, Group Leader; Biofluid Mechanics.
(*d*) Theoretical; basic research.
(*e*) Using a lumped-parameter approach, the flow of blood through the lungs is described by a coupled set of equations for the unsteady flow of a viscous liquid through distensible tubes. The equations are solved using an electronic analog computer. The purpose of the study is to develop a model capable of simulating the effects of abnormal environments (e.g., space) and/or pathological conditions.
(*f*) Suspended.
(*g*) The results show that the model gives accurate simulations of a wide range of important environmental and pathological effects. It can thus be applied to a variety of problems in environmental physiology and clinical medicine.
(*h*) **Simulation of Abnormal Pulmonary Circulatory Dynamics,** N. R. Kuchar, *Proc. 24th Ann. Conf. Engrg. Med. Biol.*, p. 68, 1971 (available from author). Final Reports, Contracts NASW-1896 and NASW-2138 (available from NASA, Washington, D.C.).

043-07990-420-00

EFFECTS OF SURFACE WAVES ON BUOY COMMUNICATIONS

(*c*) A. Pavlak.
(*d*) Theoretical; applied research.
(*e*) The present study considers the effects of surface wave blockage on the geometric conditions of a communications link between a surface following buoy and a receiving aircraft. Line of sight shadowing (UHF signal) and diffraction around the blocking wave (VHF signal) are considered. A deterministic model of a fully developed random sea has been developed and Monte Carlo techniques are used to compute the associated probability distributions.
(*f*) Completed.
(*g*) Published literature, which indicated shadowing to be a severe problem, was found to be in error. Shadowing is not a severe restriction for the system under consideration.
(*h*) GE TIS report to be published shortly.

043-07991-130-00

COAGULATION OF HYDROSOLS BY LAMINAR SHEAR FLOW

(*c*) Dr. J. H. McGinn.
(*d*) Experimental; applied research.
(*e*) The coagulation kinetics of dilute suspensions of organic and inorganic materials with ferric chloride is being investigated as a function of shear rate, solids concentration, pH and the presence of various ions. A coaxial cylinder device is being used for this investigation. These results are being applied to the design of waste treatment systems.
(*g*) Data are being analyzed. Internal reports generally of a company proprietary nature.

GENERAL ELECTRIC COMPANY, Nuclear Energy Division, Atomic Power Equipment Department, 175 Curtner Avenue, San Jose, Calif. 95114.

044-07294-140-52

TWO-PHASE FLOW AND HEAT TRANSFER IN MULTIROD GEOMETRIES

(*b*) U.S. Atomic Energy Commision.
(*c*) Dr. E. Janssen, Mail Code 583.
(*d*) Experimental and theoretical, applied.
(*e*) Measurements were made of both fully developed and developing two-phase upward flow in vertical channels, adiabatic and with heat addition, from which can be determined rates of mass and energy transfer in the transverse direction. Channel configurations included circular tube and 9-rod (3 × 3 array) bundle in square shroud. Critical boiling heat flux measurements were also made. The results will help to improve present methods for predicting the limits of heat transfer in boiling upward flow in the multirod geometries typical of boiling water reactors.
(*f*) Completed.
(*g*) Measurement of film thickness for high pressure steam/water in the circular tube, by means of a traversing probe and the McManus criterion for location of interface (probe *sees* liquid 50 percent of time and vapor 50 percent of time), shows, for mass flows greater than 0.5×10^6 lb/hr ft^2, that film thickness under boiling conditions is greater than under adiabatic conditions except near dryout. Per film sampling measurements, this greater thickness is associated with higher voids. The film thickness under both diabatic and adiabatic conditions *increases* with increasing mass flow rate for qualities less than about 22 percent and *decreases* with increasing mass flow rate for qualities greater than about 23 percent. The same unique non-dimensional film flow rate–film thickness relationship established by CISE (Italy) for argon-water is exhibited by the fully developed film data obtained on this program. The diabatic film data do not follow exactly this relationship, but can be correlated with the adiabatic data by $G_d/G_a = 1\text{–}3(\phi/10^6)(G/10^6)x$, where ϕ is heat flux in Btu/h ft^2, G is channel average mass flow rate in lb/h ft^2, and × channel average quality. Critical heat flux data, generated on another part of the program using a 9-rod bundle, show that critical heat flux is affected by the flow redistribution caused by the presence of grid-type spacers. The data also show that the inverse pressure effect (lower CHF at higher pressures for a given flow rate and quality) is stronger at higher flow rates.
(*h*) **A Study of the Liquid Film in Adiabatic Air-Water Flow With and Without Obstacles,** B. S. Shiralker, Oct. 1970 (GEAP 10248). Available NTIS, U.S. Dept. of Commerce, Springfield, Va. 22151.
Developing Two-Phase Flow in Tubes and Annuli. Part I: Experimental Results, Circular Tube; Part II: Analytical **Studies, Tubes and Annuli,** E. Janssen, J. A. Kervinen, H. T. Kim, Feb. 1971 (GEAP 10341). Available NTIS.
Two-Phase Flow and Heat Transfer in Multirod Geometries, Final Report, E. Janssen, Mar. 1971 (GEAP 10347). Available NTIS.

044-07295-140-00

STUDY OF SUBCOOLED BOILING IN TWO-PHASE FLOW

(*c*) Dr. G.E. Dix, Mail Code 583.
(*d*) Experimental and theoretical; basic research for Doctoral thesis.

(*e*) Application of hot-wire anemometer, resistance thermometer, and high speed films to the determination of void fraction profiles, temperature profiles, and condensation rates under subcooled boiling conditions. The work is directed toward the evaluation and improvement of subcooled boiling void fraction predictions.
(*f*) Completed.
(*g*) Development of an improved vapor velocity correlation. Evaluation and improvement of physical models of subcooled boiling, including bubble ejection from the surface, bubble condensation rate, and the surface heat flux division.
(*h*) Submitted as *Doctoral Thesis*, Univ. of Calif., Berkeley. Reproduced as *GE Rept.* **NEDO-10491**, Nov. 1971.

044-07988-140-52

BLOWDOWN HEAT TRANSFER PROGRAM

(*b*) General Electric Company and U.S. Atomic Energy Commission.
(*c*) G. W. Burnette, Mail Code 584.
(*d*) Experimental and theoretical, applied research.
(*e*) Program to provide data on transient heat transfer during conditions representative of a boiling water reactor undergoing hypothetical loss-of-coolant accident. Specific investigations include time to critical heat flux, lower plenum swell hydrodynamics and core thermal response, and post-critical heat flux and lower plenum swell heat transfer. Early tests oriented toward feasibility and reliability of proposed heaters (electric resistance heating of outer sheath) in multirod arrays for use at elevated temperatures. Final year of three-year program devoted to heat transfer in full-size, full-power test bundles.
(*g*) Proposed heaters are adequate for program needs; multiple heatup and cooldown in the 500 to 1500°F temperature ranges. Proposed heater design can be used to provide a good simulation of full rod thermal response.

GEORGIA INSTITUTE OF TECHNOLOGY, School of Aerospace Engineering, Atlanta, Ga. 30332. Professor J. C. Wu.

045-07992-540-15

THEORETICAL ANALYSIS OF A HOVERING ROTOR POTENTIAL FLOW FIELD

(*b*) U.S. Army Air Mobility R and D Lab.-Ames Directory.
(*d*) Theoretical, applied research.
(*e*) Analytical predictions of the performance and the induced flow fields of rotors and propellers.
(*g*) A criterion for the optimum performance of static propellers and hovering helicopter rotors is developed. Numerical results are presented relating the optimum radial distributions of circulation and inflow at the propeller disk, the slipstream contraction, and the power coefficient to the thrust coefficient. It is shown that the present theory, which fully accounts for the effect of slipstream rotation, predicts optimum distributions of circulation and inflow that differ significantly from those based on approximate methods. The theory has been extended to propellers and rotors with a non-zero axial velocity of advance.
(*h*) **Optimum Performance of Hovering Rotors,** J. C. Wu, R. K. Sigman, P. M. Goorjian, *NASA TMX 62*, 138, p. 53, Mar. 1972.
Optimum Perfomance of Static Propellers and Rotors, J. C. Wu, R. K. Sigman, P. M. Goorjian, *Progress in Theor. and Appl. Mech.* **VI**, pp. 1-25, Mar. 1972.

045-07993-740-00

AN INTEGRO-DIFFERENTIAL METHOD OF SOLUTION OF INCOMPRESSIBLE TIME-DEPENDENT NAVIER-STOKES EQUATIONS

(*d*) Theoretical, basic research; Doctoral thesis.
(*c*) A numerical method of solution of the Navier-Stokes equations aimed at the reduction of excessive computational requirements associated with previous methods is developed. The distinguishing feature of this method is an integro-differential formulation of Navier-Stokes equations. With the integro-differential formulation, mumerical computation of the potential flow field at each time step becomes unnecessary. If desired, however, the entire potential flow field can still be obtained for any time step from the vorticity distribution in the viscous flow region. The principal advantage of the new approach is a drastic reduction in the number of data points required in the numerical procedure.
(*g*) The integro-differential method has been successfullly developed and applied to several problems of practical interest. The flow past a circular cylinder has been treated and the results compared with those of previous methods. The three-dimensional viscous flow of a jet issuing from a flat plate into a crossflow has been solved for several low Reynolds number cases. Stability criterion has been developed.
(*h*) **Numerical Solution of Unsteady, Three-Dimensional Navier-Stokes Equations,** J. C. Wu, J. F. Thompson, *Proc. Project SQUID Workshop on Fluid Dynamics of Unsteady, Three-Dimensional and Separated Flows*, pp. 253-284, Purdue Univ., June 1971.
Two Approaches to the Three-Dimensional Jet-in-Cross Wind Problem; A Vortex Lattice Model and a Numerical Solution of the Navier-Stokes Equations, J. F. Thompson, *Ph.D. Thesis*, Ga. Inst. Tech., June 1971.

GEORGIA INSTITUTE OF TECHNOLOGY, School of Civil Engineering, Atlanta, Ga. 30332. William M. Sangster, Director, School of Civil Engineering.

046-06690-200-00

UNSTEADY OPEN CHANNEL FLOW

(*c*) Dr. C. S. Martin.
(*d*) Experimental and theoretical; Ph.D. thesis.
(*e*) The equations of motion for unsteady gradually varied open channel flow are expressed in a finite difference form suitable for programming on a high-speed digital computer. For subcritical flow the theory and computer program were tested and the results compared with existing experimental results corresponding to the following situations: (1) flood hydrograph in circular channel; (2) power load rejection in headrace of trapezoidal canal; (3) power load acceptance in tailrace of rectangular model channel; and (4) tidal (stage) hydrograph in rectangular model estuary. The stability of the finite-difference method was tested for such severe flow situations as the dam break problem. A finite-difference method was also developed for unsteady supercritical flow. The numerical stability and instability of unsteady supercritical flow corresponds somewhat with established criteria based on experiment and analyses. An experiment was conducted in a flume for which a moving hydraulic jump produced both subcritical and supercritical flow in the same channel. A finite-difference scheme was developed that simulated both regimes well.
(*h*) **Finite-Difference Simulation of Bore Propagation,** *J. Hyd. Div., Proc. ASCE* **97**, HY7, pp. 993-1010, July 1971.
Graphical and Computer Analysis of Tailrace Surges, *J. Power Div., Proc. ASCE* **97**, PO3, pp. 697-706, July 1971.
The Numerical Solution of Transient Supercritical Flow by the Method of Characteristics with a Technique for Simulating Bore Propagation, J. J. Zovne, *Ph.D. Dissertation*, Ga. Inst. of Tech., 1970.

046-06692-220-33

EFFECT OF A PERMEABLE BED ON SEDIMENT TRANSPORT

(*b*) Office of Water Resources Research.

(*c*) Dr. C. S. Martin.
(*d*) Experimental; basic research.
(*f*) Completed.
(*g*) The effective seepage force on cohesionless interfacial bed particles that comprise a plane bed was determined experimentally from the results of slope instability tests and from extrapolation of the results of erosion tests. Using two sand columns, one square and the other circular in cross section, the seepage flow was either into or out of the bed for the slope instability tests. For uniform sand particles ranging from 0.46mm to 0.72mm diameter the seepage force on the interfacial sand grains was determined to be one-half the seepage force on particles well within the bed. Erosion of the sand bed was measured for seepage flow vertically upward and into the bed subsequent to instability of the bed. From an extrapolation of the results of the erosion tests to zero erosion, which was assumed to correspond to the condition of incipient instability, it is concluded that the seepage force on the interfacial grains is approximately 35 to 40 percent of the seepage force on the grains well within the bed. Incipient-motion tests were conducted with and without seepage. It was found that seepage may either enhance or hinder incipient motion, depending on the relative magnitude of the boundary shear stress and the seepage force, both of which depend upon the seepage flow. For a given hydraulic gradient for seepage into a bed the size of the sand grains is critical regarding incipient motion. Incipient motion may be hindered for smaller sand grains but enhanced for larger sand grains. For the same hydraulic gradient the greater permeability associated with the larger sand grains results in a greater seepage velocity, and a correspondingly greater shear stress. Tests on the effect of seepage on the bed-load carrying capacity of a stream indicated that sediment transport is not measurably impaired by seepage into a bed, unless fine particles of the sand mixture or foreign material are deposited in the bed, resulting in a concreting effect. Tests indicated that seepage flow into a bed in the vicinity of non-uniform flow aids the suspended-load carrying capacity of the stream by inducing strong secondary currents. For practical values of the magnitude of the hydraulic gradient, that is less than unity, the effect of seepage on incipient motion and sediment transport is not expected to be significant, however.
(*h*) **Effect of a Porous Sand Bed on Incipient Sediment Motion,** *Water Resour. Res.* 6, 4, pp. 1162-1174, Aug. 1970.
Behavior of Porous Bed Near Flow Singularity, *J. Soil Mech. Div., Proc. ASCE* **97,** SM2, pp. 393-415, Feb. 1971.
Seepage Force on Interfacial Bed Particles, C. S. Martin, M. M. Aral, *J. Hyd. Div., Proc. ASCE* **97,** HY7, pp. 1081-1100, July 1971.

046-06693-070-00

SOLUTIONS OF SEEPAGE THROUGH COMPLEX MEDIA BY FINITE ELEMENTS

(*c*) Dr. P. G. Mayer.
(*d*) Theoretical; basic research.
(*e*) Seepage through naturally occurring materials frequently requires treatment of media which are seldom isotropic and more often nonhomogeneous. The method of finite elements is a general numerical method by which complicated seepage problems can be effectively conditioned for digital computation.
(*h*) **Solution of Anistropic Seepage by Finite Elements,** O. Zienkiewicz, Y. K. Cheung, *J. Engrg. Mech. Div., ASCE Proc.*, EM1, Feb. 1966, pp. 111-120.
Numerical Modeling in Fluid Mechanics, B. R. Olmstead, *M.S. Thesis*, Ga. Inst. Tech., Sept. 1968, 79 pages.

046-06695-250-61

UNSTEADY FLOW OF DILUTE AQUEOUS HIGH POLYMER SOLUTIONS IN PIPES

(*b*) Water Resources Center.
(*c*) Dr. P. G. Mayer.
(*d*) Theoretical and experimental; basic research.
(*e*) Small traces of certain long-chain polymeric molecules, dissolved in water, reduce turbulent friction in flow through pipes. Local additions of polymers will change the resistance characteristics almost instantly, and the progress of the fluid slug with changed properties is a time dependent process. A mathematical study of head and velocity changes is to be carried out using numerical procedures and an electronic digital computer. The mathematical problem is to be formulated as an initial value problem. Solutions to simple pipe problems involve the Runge-Kutta procedures and the Adams-Bashforth method. A laboratory study of unsteady pipe flow is to verify the mathematical model. The mathematical procedures are to be extended to parallel pipe systems and to pipe networks.
(*g*) Experiments carried out in a 2-inch diameter pipe demonstrated that a 40 percent reduction resulted from admixture of 100 parts per million by weight. Reductions as much as 60 percent were observed at polymer concentrations of 300 parts per million. The experiments were carried out as steady-state processes. The basic simple pipe unsteady pipe flow problem has been solved numerically. Laboratory experiments are under way to verify the procedures.
(*h*) **Unsteady Flow of Aqueous Solution of Long-Chain Polymers in Pipe Networks,** H. C. Jackson, *M.S. Thesis*, Ga. Inst. Tech., Jan. 1970, 135 pages.
Unsteady Flow of Dilute Aqueous Polymer Solutions in Pipe Networks–A Method to Improve Water Distribution, *WRC Rept. 0170*, Water Resour. Ctr., Ga. Inst. Tech., Feb. 1970, 139 pages.

046-06699-430-00

DYNAMIC RESPONSE FUNCTIONS OF OCEAN STRUCTURES

(*c*) Dr. P. G. Mayer.
(*d*) Theoretical; Ph.D. thesis.
(*e*) The object of the study is to develop a technique for analyzing the dynamic response of off-shore structures subjected to random wave forces and to the constraints imposed by the foundation medium of the ocean floor. Emphasis is placed on the use of existing models of the forcing functions and the restraining functions to formulate a numerical method analysis. The structural model is analyzed for free and random vibrations. Cross-power spectra are developed for random force fields and random wave heights. Consideration is given to fluid damping and the effects of vortex shedding. Dynamic resistance of soils to the movements of piles is to be included. The finite element method may be used in the analysis of dynamic foundation response.
(*h*) **Dynamic Structure-Soil-Wave Model for Deep Water,** *J. Waterways, Harbors and Coastal Engrg. Div., ASCE*, Paper No. 7889, Feb. 1971, pp. 107-184.
An Analysis Technique for Composite Structures Subject to Dynamic Loads, *Trans. ASME* **38,** Series E, 1, Mar. 1971, pp. 118-124.
An Analysis Technique for Designing Deep Ocean Structures, *Proc. Coll. Intl. sur l'Exploitation des Oceans, Theme III, Tome II, G 1-11*, p. 1-5, Mar. 1971.

046-07298-130-00

AIR ENTRAINMENT IN ENCLOSED CONDUITS

(*c*) Dr. C. S. Martin.
(*d*) Experimental; basic and applied research.
(*e*) The formation of hydraulic jumps in sloping conduits and the transition from bubbly flow to slug flow in a vertical shaft are currently being studied. Model studies were conducted on an outfall line for the purpose of removing air entrained by moving hydraulic jumps. Air was removed by using simulated air release valves. Entrainment of air into vertical shaft through Borda-type entrances is being studied. Air demand at inlet is measured. Instability of nappe and resultant pressure fluctuations and vibrations are being measured and studied. Formation of slug flow and subsequent blow back or blow out is also being studied.

(*h*) **Vertically Downward Bubbly and Slug Flow of an Air-Water Mixture in a Pipe,** in press.

046-07300-220-00

TRANSPORT CHARACTERISTICS OF LOG-NORMAL DISTRIBUTED BED MATERIALS IN OPEN CHANNELS

(*c*) Dr. P. G. Mayer.
(*d*) Theoretical and experimental; Ph.D. thesis.
(*e*) Information is sought on the interaction of the turbulence structure in open channel flow and the bed load movement of log-normally distributed bed materials. Time-dependent measurements are made of sediment transport and size distributions. Turbulence measurements are made with a constant temperature hot-film anemometer. The phenomenon of armoring is investigated.
An Experimental Study of Bed Armoring, *Proc. Einstein Sediment Symp.*, Univ. Calif., Berkeley, June 1971.

046-07301-370-47

EVALUATION OF DESIGN METHODS OF SUBSURFACE DRAINAGE FACILITIES FOR HIGHWAYS

(*b*) State Highway Dept. of Ga.; Federal Highway Administration.
(*c*) Dr. G. M. Slaughter.
(*d*) Theoretical and field investigation; applied research and design.
(*e*) The purpose is to evaluate the design methods and construction procedures currently used on the drainage facilities designed for the removal of subsurface waters (regardless of origin) from the immediate vicinity of the highways. The scope of the project consists of determining the origin of the existing methods as used in Georgia; finding out what has been and is being done elsewhere; evaluating the effectiveness of current design methods used in Georgia; recommending appropiate changes where necessary; and determining the feasibility and need for further studies in this area.

046-08009-370-70

DEVELOPMENT OF PROGRAMMED REMOVAL FOR CAPSULE-TRANSPORT SYSTEM–TUBEXPRESS

(*b*) Trans-Southern Pipe Line Corporation.
(*c*) Mr. D. W. Leva, Trans-Southern Pipe Line Corp., P.O. Box 1396, Houston, Texas.
(*d*) Applied research and development.
(*e*) A capsule-transport system was developed at Georgia Tech which was subsequently licensed to Trans-Southern Pipe Line Corporation. (See 7297 in previous issues.) This project is a further development of the system to allow programmed removal of a car at a preselected station. The conduit is 364 ft. long, 48 in. high, and 40 in. wide. The project involves development of a complete loading station where a car is removed from the conduit, is decelerated, is stopped for loading and/or unloading, and is reinjected with new instructions for the next removal.

046-08010-350-73

EFFECT OF PIER SHAPES AND PIER LOCATIONS ON SPILLWAY CAPACITIES

(*b*) Georgia Power Company.
(*c*) Dr. P. G. Mayer.
(*d*) Applied research.
(*e*) Laboratory studies are conducted to obtain design criteria. 1:100 and 1:60 hydraulic models are tested.

046-08011-340-73

RESERVOIR CIRCULATION IN A PUMPED-STORAGE PROJECT

(*b*) Georgia Power Company.
(*c*) Dr. P. G. Mayer.
(*d*) Theoretical, applied research.
(*e*) A 30 × 50 foot laboratory model was built on a distorted scale (1:400 horizontal, 1:60 vertical). Studies being conducted to establish near-field and far-field circulation patterns. The project is designed to provide design information for the Wallace Dam Pumped-Storage Project of the Georgia Power Company.

046-08012-360-73

CROSS-FLOW ASSISTED HYDRAULIC JUMPS

(*b*) Georgia Power Company.
(*c*) Dr. P. G. Mayer.
(*d*) Theoretical and applied research.
(*e*) Cross-flow assisted hydraulic jumps form at conjugate depths less than those predicted by two-dimensional momentum analysis. The studies are intended to explain the phenomena and to establish design criteria.

046-08013-350-00

SPILLWAY CREST PRESSURES AT PARTIALLY OPEN TAINTER GATES

(*c*) Dr. P. G. Mayer.
(*d*) Theoretical and applied; M.S. thesis.
(*e*) Dam spillway standard crest shapes are often designed for about 75 percent of the design head in order to obtain greater discharge capacity. This procedure results in negative pressures which have been measured. The addition of tainter gates as crest control structures provides for the opportunity to discharge from partially open gates. The jet trajectory from the partially open tainter gates is different from that used for the design of the standard overflow spillways. The study is intended to delineate the limiting condition which would prevent the occurrence of cavitation and cavitation damage.

046-08014-740-00

FINITE ELEMENT ANALYSIS IN FLUID MECHANICS

(*c*) Dr. P. G. Mayer.
(*d*) Theoretical.
(*e*) Development of detailed mathematical and numerical analysis involved in the finite element method. A computer program is developed and selected applications are studied.
(*h*) **Application of Finite Element Analysis in Fluid Mechanics,** *Ph.D. Thesis*, Ga. Inst. Tech., Aug. 1971.
Finite Element Galerkin Method Solutions to Selected Elliptic and Parabolic Differential Equations, *Air Force 3rd Conf. on Matrix Methods in Structural Mechanics*, Oct. 1971, 28 pp.

GEORGIA INSTITUTE OF TECHNOLOGY, School of Engineering Science and Mechanics, Atlanta, Ga. 30332. Dr. Milton E. Raville, Director, School of Engineering Science and Mechanics.

047-07302-240-00

HYDROELASTIC OSCILLATIONS IN UPRIGHT CIRCULAR CYLINDER

(*c*) Dr. H. F. Bauer.
(*d*) Theoretical; applied research.
(*e*) Behavior of incompressible and nonviscous liquid with free surface in an upright circular cylindrical container is treated. Free and forced oscillation with arbitrary wall- and bottom-excitation is covered and determination of coupled frequencies of liquid-structure system for elastic bottom and wall (shell equations) is indicated.
(*f*) Completed.
(*h*) **Hydroelastische Schwingungen im aufrechten Kreiszylinderbehaelter,** H. F. Bauer, *Zeitschrift fuer Flugwissenschaften* **18,** 4, Apr. 1970, pp. 117-134.

047-07304-240-00

DYNAMIC INTERACTION OF A LIQUID WITH THE ELASTIC STRUCTURE OF A CIRCULAR CYLINDRICAL CONTAINER

(*c*) Dr. H. F. Bauer; Dr. J. Siekmann.
(*d*) Theoretical; applied research.
(*e*) Investigates the general case of hydroelastic coupled oscillation of a partially filled liquid container with flexible bottom and an elastic sidewall (Donnell's equation). Bottom is either flexible membrane or thin elastic plate.
(*f*) Completed.
(*h*) **Dynamic Interaction of Liquid with the Elastic Structure of a Circular Cylindrical Container,** H. F. Bauer, J. Siekmann, *Ingenieur Archiv* **40,** pp. 266-280, 1971.

047-07305-240-50

FLUID BEHAVIOR IN A LONGITUDINALLY EXCITED CYLINDRICAL TANK OF ARBITRARY SECTOR-ANNULAR CROSS-SECTION

(*b*) NASA-Institutional Grant.
(*c*) Dr. H. F. Bauer and Dr. J. Woodward (Bauer; School of Engrg. Sci. and Mech., Ga. Inst. Tech., and Woodward; Univ. of Alabama, Birmingham).
(*d*) Theoretical; applied research, thesis.
(*e*) Response of liquid free surface motion is presented for a longitudinally excited container with annular circular sector cross-section. Depending on the excitation parameters, the free surface will remain a plane or oscillate with a finite amplitude. The finite amplitude motion can be subharmonic, harmonic or superharmonic. The importance of the harmonic and superharmonic is considerably lessened because of stability considerations. Forces and moments are obtained.
(*f*) Completed.
(*h*) **Fluid Behavior in a Longitudinally-Excited, Cylindrical Tank of Arbitrary Sector-Annular Cross-Section,** H. F. Bauer, J. Woodward, *AIAA J.* **8,** 4. pp. 713-719, 1970.

047-07308-130-50

THEORETICAL INVESTIGATION OF GAS MANAGEMENT IN ZERO-GRAVITY SPACE MANUFACTURING

(*b*) NASA, Marshall Space Flight Center, Huntsville, Ala.
(*c*) Dr. H. F. Bauer.
(*d*) Theoretical; applied research.
(*e*) Behavior of spinning liquid-gas system under zero gravity; determination of geometrical shape and location of globe and gas bubble as function of surface tension, chamber pressure, rotational speed and volumes migration of gas bubble.
(*h*) **On the Shape of a Rotating Fluid System Consisting of a Gas Bubble Enclosed in a Liquid Globe,** H. F. Bauer, J. Siekmann, *ZAMP* **22,** pp. 532-542, 1971.

047-08015-240-00

AXISYMMETRIC HYDROELASTIC SLOSHING IN A CIRCULAR CYLINDRICAL CONTAINER

(*c*) Dr. H. F. Bauer, Dr. J. T. S. Wang, Dr. P. Y. Chen, (Bauer and Wang; School of Engrg. Science and Mech., Ga. Inst. Tech., and Chen; Res. and Dev. Div., Babcock and Wilcox, Alliance, Ohio).
(*d*) Theoretical; applied research.
(*e*) Behavior of incompressible and nonviscous liquid with free surface in a circular cylindrical container with elastic wall and elastic bottom (thin plate) has been obtained for axisymmetric case. Coupled frequencies were obtained for various wall and bottom thicknesses.
(*f*) Complete.
(*h*) **Axisymmetric Hydroelastic Sloshing in a Circular Cylindrical Container,** H. F. Bauer, J. T. S. Wang, P. Y. Chen, *J. Royal Aero. Soc.* (accepted).

047-08016-240-00

NONLINEAR LIQUID MOTION IN A LONGITUDINALLY EXCITED CONTAINER WITH ELASTIC BOTTOM

(*c*) Dr. H. F. Bauer, Dr. S. S. Chang, Dr. J. T. S. Wang, (Bauer and Wang; School of Engrg. Sci. and Mech., Ga. Inst. of Tech., and Chang; Preston H. Haskel Co., Jacksonville, Fla.).
(*d*) Theoretical; applied research.
(*e*) Liquid motion in a circular cylindrical container subjected to longitudinal excitation of sinusoidal form is investigated for incompressible and nonviscous liquid. The container bottom is treated as a thin elastic plate, while the dynamic and kinematic conditions of the free liquid surface are represented by nonlinelar equations. Depending on the excitation parameters, the free surface will exhibit a plane surface or oscillate with finite amplitude of one-half subharmonic, harmonic, or superharmonic of the excitation frequency. It was found that the influence of the elastic bottom upon the response of the liquid is more significant as tank diameter increases and bottom thickness decreases. Liquid height is also affecting the liquid response, indicating that for decreasing height the influence of the elastic bottom upon the liquid response becomes more important. Results were obtained for a Saturn-Apollo-Booster.
(*f*) Completed.
(*h*) **Nonlinear Liquid Motion in a Longitudinally Excited Container with Elastic Bottom,** H. F. Bauer, S. S. Chang, J. T. S. Wang, *AIAA J.* **9,** 12, Dec. 1971, pp. 2333-2339.

047-08017-130-50

THEORETICAL INVESTIGATION OF GAS MANAGEMENT IN ZERO-GRAVITY SPACE MANUFACTURING

(*b*) NASA, Marshall Space Flight Center, Huntsville, Ala.
(*c*) Dr. H. F. Bauer.
(*d*) Theoretical; applied research.
(*e*) In the casting of a material under the lack of gravity, gas bubbles are trapped in the liquified material. To remove these, the material is electromagnetically spun up. For this degassing process of the material, the time required for a bubble to move under the action of the centrifugal force is determined for small and large bubble sizes. Velocity and time of migration have been determined.
(*f*) Completed.
(*h*) **Migration of a Large Gas-Bubble Under the Lack of Gravity in a Rotating Liquid,** H. F. Bauer, *AIAA J.* **9,** 7, pp. 1426-1427, 1971.

047-08018-240-00

HYDROELASTIC VIBRATIONS IN A UNIFORMLY ROTATING INFINITELY LONG CIRCULAR CYLINDRICAL CONTAINER

(*c*) Dr. H. F. Bauer.
(*d*) Theoretical; applied research.
(*e*) The behavior of an incompressible and nonviscous liquid with a free surface in a uniformly fast rotating infinitely long elastic circular cylinder is treated. The natural frequencies of the liquid in a rigid container, as well as the response of the liquid to forced rigid and elastic container wall excitations are presented. Furthermore, the determination of the hydroelastic spin-slosh problem is presented, since the elasticity of the spinning container wall may considerably influence the magnitude of the coupled frequencies of the liquid-structure system.
(*f*) Completed.
(*h*) **Hydroelastic Vibrations in a Uniformly Rotating Infinitely Long Circular Cylinder,** H. F. Bauer, *Acta Mechanica* **12,** 1971, pp. 307-326.

GRUMMAN AEROSPACE CORPORATION, Research Department, Bethpage, N.Y. 11714. Dr. Charles E. Mack, Jr., Director of Research.

048-08019-610-00

DYNAMIC ANALYSIS OF HYDRAULIC NETWORKS

(*c*) Dr. W. Hill, Research Scientist.
(*d*) Theoretical, applied research.
(*e*) A computer-aided analysis to determine the pressure and flow variations through complex hydraulic networks. The theory is based on the impedance method and the response of networks to sinusoidal disturbances. The uniqueness of this project is that analysis can be accomplished quickly and relatively cheap for highly complex networks and their modifications. In addition, the effects of freely moving or unsecured hydraulic lines are accounted for.
(*f*) Suspended.
(*g*) The analysis has demonstrated excellent agreement with experimental data published by Purdue University and NASA/Lewis Research Center.

048-08020-130-00

GAS BUBBLE-LIQUID FLOW INTERACTIONS

(*c*) Dr. S. Gutti, Research Scientist.
(*d*) Theoretical, applied research.
(*e*) A computer-aided analysis of the behavior of small gas bubbles in accelerated/decelerated liquid flows, and the effects of convergent-divergent (nozzle) conduit geometry on two-phase flows. The initial part is significant to water aeration considerations and the latter part has potential value to energy conversion processes.
(*g*) Terminal velocities and displacement heights of bubbles rising through a liquid in a vertical diffuser can be determined by the analysis. The examination of nozzle conduit shape for various gas bubble-liquid flows has shown that increasing the convergent approach length reduces the bubble slip velocity and the liquid phase velocity; there appears to be an optimum length associated with certain operational conditions to yield maximum liquid outlet velocity. The nozzle length also appears to have less of an effect on bubble size change than on slip velocity.
(*h*) **Movement of Small Gas Bubbles in a Smoothly Decelerating Liquid,** S. Gutti, *Grumman Res. Dept. Memo. RM-499J;* also *ASCE J. Hydraul. Div.* **97,** HY7, July 1971.

048-08021-700-00

HOT-FILM ANEMOMETRY IN LIQUIDS

(*c*) K. M. Foreman, Research Engineer.
(*d*) Experimental, development.
(*e*) This project is developing improved hot-film velocity sensors for use in and applications to water research. The objective is to attain long-lived (e.g., order of months) capability to measure velocity and turbulence in saline and polluted liquids, and exhibit high reliability and performance.
(*g*) Use of Teflon film protected, parabolic-shaped sensors in ocean and estuarine waters has encouraged belief that 30-day operational capability is attainable. Directional sensitivity of these sensors in water is being examined using a special test chamber. Extension of this project to open channels of varying cross-section has indicated that the sensors have extremely good spatial resolution to measure nonuniform velocity profiles, circulation patterns, and to discriminate the air-liquid interface.
(*h*) **Some Operational Characteristics of Hot-Film Water Velocity Sensors,** K. M. Foreman, *Grumman Res. Dept. Memo. RM-501J;* presented at AIP, ISA, ASME, NBS Symp. on Flow Measurement, Pittsburgh, Pa. (May 1971).

UNIVERSITY OF HAWAII, J. K. K. Look Laboratory of Oceanographic Engineering, Department of Ocean Engineering, 811 Olomehani Street, Honolulu, Hawaii 96813. John Thomas O'Brien, Director of the Laboratory. (Direct report requests to; The Director)

050-08110-470-60

HYDRAULIC MODEL STUDY OF KEWALO SMALL CRAFT BASIN OAHU, HAWAII

(*b*) State of Hawaii; Dept. of Transportation; Harbors Division.
(*c*) F. Gerritsen and/or A. R. Fallon, Chevron Oil Field Research Co., P.O. Box 446, La Habra, Calif. 90631.
(*d*) Applied experimental type research in the laboratory.
(*e*) As an aid to design, to determine ways to reduce wave disturbances in the entrance channel. All without significant disturbance to important surfing reefs on either side of the channel entrance. A 1/75 linear scale hydraulic model with fixed beds was used for the purpose.
(*f*) Completed.
(*g*) To reduce the disturbances it was recommended that the following be constructed: a 200 ft. long nearly submerged jetty to protect the starboard side of the channel; dredging of a reef in the channel to 20 ft. depth; rubble rock absorbers around the periphery of the Basin.
(*h*) **Model Investigation of Improvements to Kewalo Basin,** A. R. Fallon, F. Gerritsen, R. Q. Palmer, S. P. Sullivan, *TR-17, J.K.K. Look Lab.,* July 1971, 90 pages.

050-08111-410-44

SAND RECOVERY OFF HAWAII

(*b*) Office of Sea Grants, Natl. Ocean. and Atmos. Administration.
(*c*) F. M. Casciano.
(*d*) Development task in the ocean.
(*e*) To develop a Submarine Sand Recovery System (SSRS); to develop a recovery technique suitable for a small contractor; to involve local and other agencies in the task preferably with their financial support. The SSRS features a hydraulic dredge of the suction type with a head which is jetted to the bottom of a sand deposit. As sand is pumped out, to a barge or directly onto a beach, the material above collapses into the cavity formed. Eventually a stable crater is formed and sand removal ceases. The intake features a device to reduce clogging. It is a powered crusher-feeder which breaks down large particles such as coral chunks, before they enter the intake pipe. A model, with 3 in. OD p.v.c. pipes, has been tested successfully in a submarine canyon off Waikiki in about 30 ft. of reef-protected water. A 6 in. OD steel pipe model is under construction with tests planned in late 1972 possibly in the harbor of Hilo, Hawaii.
(*h*) **Potential of Offshore Sand as an Expendable Resource in Hawaii,** F. M. Casciano, R. Q. Palmer, *TR-11, J.K.K. Look Lab,* Dec. 1969; 32 pages.
Sand Coring in the Halekulani Sand Channel..., F. M. Casciano, R. Q. Palmer, *TR-12, J.K.K. Look Lab.,* May 1970, 35 pages.
Effects of Sand Removal on a Coral Community, A Literature Review of, J. Levin, *TR-19, J.K.K. Look Lab.,* Dec. 1970, 78 pages.

050-08112-420-60

HAWAIIAN SURF PARAMETERS

(*b*) State of Hawaii.
(*c*) J. R. Walker.
(*d*) Applied research mainly in the ocean aided by theoretical and experimental studies in the laboratory and some development (of an artificial reef mainly for surfing).
(*e*) The study is being conducted "... so that shoreline projects can be planned and executed with improved knowledge relating to ocean wave phenomena especially relating to shoals and land masses...(and).. to obtain information...in order to protect and enhance safety, navigation activities, recreation facilities, and other shoreline interests..." (Act

175 of 1970 Hawaiian Legislature). Surf parameters, for a particular surfing area, include location, hydrography, winds, waves, currents, compositon of bottom, use, ingress-egress and effect on coastline.

(*f*) Completion date July 1973.

(*g*) From Sept. 1971 to start of April 1972, surf parameters of six surfing areas off Oahu have been measured; the mathematics description of breakers has been improved, including wave energy description in surf board recovery areas; a concept for an artificial surfing reef has been evolved and tested successfully at reduced scale in the laboratory. It is intended to provide for surfing, enhance marine life, and protect the coastline.

(*h*) **Surf Parameters: Interim Report,** J. R. Walker, R. Q. Palmer, J. M. Kelly, Jr., *Tr-16, J.K.K. Look Lab.*, Feb. 1971, 147 pages.

Surf Parameters: A General Surf Site Concept, J. R. Walker, R. Q. Palmer, *TR-18, J.K.K. Look Lab.,* Sept. 1971, 47 pages.

Recreation Surfing in Hawaii, J. R. Walker, R. Q. Palmer, J. K. Kukea, *Proc. 13th Conf. Coastal Engrg., ASCE*, 1972.

Artificial Reefs, J. R. Walker. Chap. 5, *Topics in Ocean Engineering*, Gulf Publishing Co. (in press).

050-08113-410-44

HAWAIIAN BEACH AND SURF PARAMETERS

(*b*) Office of Sea Grants, Natl. Ocean. and Atmos. Administration.

(*c*) F. Gerritsen and/or U. Nayak.

(*d*) Applied experimental type research in the field.

(*e*) Determine seasonal and long-term rates of sand loss or accretion; identify relationship among dominant parameters such as breaking, refraction, diffraction, surf, setup, surge, currents, sand transfer; predict extent of erosion; train students in pertinent techniques.

(*f*) Firm through Sept. 1973.

(*g*) Beaches at Haleiwa, Waimanalo, Pokai Bay, and especially at Waikiki, all on Oahu, Hawaii, have been studied. Definite conclusions are not available.

050-08114-870-65

WATER PROPERTIES OF KAILUA BAY, OAHU, HAWAII

(*b*) City and County of Honolulu, Hawaii.

(*c*) K. H. Bathen.

(*d*) Applied research in the ocean.

(*e*) Provide baseline information for a sewer outfall soon to be constructed in the Bay.

(*f*) Completion date is Sept. 1972.

(*g*) Measurements are being made of currents in the Bay and of temperature and salinity along with concentrations of certain nutrients especially derivatives of phosphorous and nitrogen. Analysis is directed to provide information especially on seasonal changes in circulation and water properties in the Bay and of dilution at the proposed outfall discharge points.

050-08115-470-10

HYDRAULIC MODEL STUDY OF HALEIWA SMALL CRAFT HARBOR, OAHU, HAWAII

(*b*) Corps of Engineers, U.S. Army, Pacific Division.

(*c*) T. T. Lee.

(*d*) Applied experimental type research in the laboratory.

(*e*) As an aid to design, to test and report on plans by the Corps for the improvement of the protection of the harbor against wind generated waves without disturbing adversely the beach east of the harbor entrance. The plans considered include deepening and the extension of the outer mole.

(*f*) Due to be completed Nov. 1972.

(*g*) A fixed bed 1/75 linear scale undistorted-model of about 2400 sq. ft. has been constructed and is being used to predict wave behavior in the ocean and harbor. Measurements of water level variations have been attempted at the harbor itself but have been unrewarding due to "flat" seas at time of measurement.

(*h*) **Hydraulic Model Study of a Small Boat Harbor Located at Haleiwa, Oahu, Hawaii,** T. T. Lee, *Misc. Rept. No. 3*, J. K. K. Look Lab. Repts. 3A, B, C and D dated, respectively, Jan., Feb., Mar. and Apr. 1972, have been issued.

050-08116-470-10

EFFECT OF HYDRAULIC DREDGING IN KAWAIHAE HARBOR, HAWAII

(*b*) Corps of Engineers, U.S. Army, Pacific Division.

(*c*) F. Gerritsen and/or S. P. Sullivan, Jr. Researcher.

(*d*) Applied experimental type research in the field.

(*e*) Objectives in this mainly coral based harbor are to obtain measurements of water quality in the dredge discharge system; siltation effects on the seabed and harbor bottom both around the areas being dredged and around the discharge system; dredging operation parameters for correlation with the aforementioned water quality and siltation measurements.

(*f*) Completion date is Sept. 1972.

(*g*) Measurements are being made of dredge output and of water circulation and tidal variation and the properties of the water including suspended and bed load, salinity and concentrations of nutrients such as derivatives of phosphorous and nitrogen.

050-08117-370-44

MARINE ALTERNATIVES FOR MASS TRANSIT IN HAWAII

(*b*) Office of Sea Grants, NOAA; State of Hawaii, Office of Marine Affairs Coordinator.

(*c*) T. T. Lee.

(*d*) Literature-numerical study in the office.

(*e*) Determine the feasibility of operating a fleet of boats for public—transportation in the existing waterways in the Honolulu area as a complement to a land-based rapid transit system. The physical, economic, demographic and social environment is being studied along with the improvements and alterations required, such as dredging and bridge building and relocation.

(*f*) Completion is due Sept. 1973.

(*g*) Basic data is being collected and coordination with pertinent agencies is being established.

050-08118-720-44

OPERATION OF HYPERBARIC FACILITIES

(*b*) Office of Sea Grants, NOAA.

(*c*) J. T. O'Brien.

(*d*) Operation, maintenance and development of hyperbaric facilities.

(*e*) A steel cylindrical tank called the "Deep Tank," 40 ft. high and 30 ft. in diameter with 40" OD hatch on top and side, is available. This can be filled with water and/or air to 4 atmospheres absolute (ATA) pressure with the aid of an air compressor. An 8 ft. long by 40-inch OD cylindrical lock to 11 ATA is part of the side hatch. A four component diving system to 19 ATA is being installed. It consists of two cylindrical decompression chambers each about 8 ft. long and 54 inches OD; one 54-inch OD spherical lock and one 9 ft. high by 72-inch OD cylindrical diving bell. A three component wet and/or dry facility to 100 ATA has been designed complete with plans, specifications and cost estimate. It consists of two cylindrical tanks, one 20 ft. long by 8 ft. OD and the other 10 ft. long by 50 inches OD. Both are attached in line to either side of an 8-ft. OD spherical lock. These facilities are operated for the benefit of researchers in general. To date the researchers have been from the Dept. of Physiology and concerned with Human Performance in the Sea, along with researchers from the Dept. of Pharmacology and Psychology.

(*f*) Firm through Aug. 1973.

(*g*) Studies currently on the way and planned in the Deep Tank include experiments with humans on breath-hold div-

ing bradycardia, a reflex slowing of the heart, and on maximal submerged work capacity, especially as effected by temperature and water depth.

(*h*) **Human Performance in the Sea,** T. O. Moore, *Look Lab/Hawaii* **1**, 3, 42-43, July 1970.

050-08119-520-54

RESPONSE OF MOORED SHIPS TO IRREGULAR SEAS

(*b*) National Science Foundation.
(*c*) L. H. Seidl.
(*d*) Applied numerical type research in the office.
(*e*) To develop design diagrams for the prediction of the motion of ships moored in irregular seas. Conventional theory is being used along with computers.
(*f*) Due for completion Aug. 1972.
(*g*) Significant double amplitudes of surging, heaving, and pitching motions of moored ships in irregular seas have been calculated and plotted as ship length versus the motion for sea states 3 through 7. Computation of the amplitudes of the other three motions is underway.
(*h*) **Surging, Heaving and Pitching of Moored Ships in Irregular Seas,** L. H. Seidl, *TR-20*, *J. K. K. Look Lab.*, Sept. 1971, 19 pages.
Surging, Heaving and Pitching of Moored Ships in Irregular Seas, L. H. Seidl, *TR-21*, *J. K. K. Look Lab.*, Sept. 1971, 92 pages.
Comparison of Surging, Heaving, and Pitching from a Computer with Experimental Results, L. H. Seidl, *TR-22*, *J. K. K. Look Lab.*, Nov. 1971, 55 pages.

050-08120-420-00

WATER WAVE FORECASTING FOR DESIGN

(*c*) C. L. Bretschneider.
(*d*) Applied research in the office.
(*e*) Prediction of operational sea states and design wave conditions as an aid to the design of offshore and coastal structures.
(*g*) A method (Bretschneider 1972) for forecasting hurricane-generated water waves has been developed which is a significant improvement over "Revisions in Wave Forecasting: Deep and Shallow Water," by C. L. Bretschneider; Proc. 6th Conf. Coastal Engr., ASCE, 1958, p. 30-67.
(*h*) **Forecasting Relations for Wave Generation,** C. L. Bretschneider, *Look Lab/Hawaii* **1**, 2, Apr. 1970, pp. 31-34.
A Non-Dimensional Stationary Hurricane Wave Model, C. L. Bretschneider, preprint, *Paper No. 1517*, *Offshore Tech. Conf.*, ASCE and Others, Apr. 1972, p. I-53-I-68.
Revisions of Hurricane Designing Wave Practices, *Proc. 13th Conf. Coastal Engr., ASCE*, July 1972.
Coastal Engineering Practices, C. L. Bretschneider, Chap. 18 (p. 489-501), in *Impingement of Man on the Oceans*, John Wiley and Sons, Inc., 1971.

050-08121-420-00

MEASUREMENT OF OCEAN WAVE PARTICLE VELOCITIES

(*c*) R. A. Grace and/or R. Y. Rocheleau.
(*d*) Basic research using a measuring system based on the ocean bottom in 40 ft. of water off Oahu about [illegible] miles NW off Waikiki.
(*e*) Determine water particle velocities near the ocean bottom due to wave action. Measurements are being made using two ducted current meters and a water level variation (wave) pressure sensor. Two seven-conductor armored cables transmit power to instruments, and impulses from instruments to shore-based recorders.
(*f*) Suspended; the first stage of field work has been completed. Measuring will resume Aug. 1972.

ILLINOIS INSTITUTE OF TECHNOLOGY, Department of Chemical Engineering, Chicago, Ill. 60616. Dr. D. T. Wasan, Department Chairman.

051-08023-610-70

FLOW ATTACHMENT TO SOLID SURFACES; THE COANDA EFFECT

(*b*) Chicago Bridge and Iron Company.
(*d*) Experimental; basic research for Masters.
(*e*) Elucidate the governing mechanism behind a potentially useful physical phenomenon. A description of the mechanism will enable the design of appropriate engineering types of apparatus.
(*f*) Activity contingent upon availability of funds.
(*g*) To date macroscopic model has been defined based upon a photographic study using a birefringent dye solution. Quantitative velocity and pressure profile data has been obtained to support the model.

ILLINOIS INSTITUTE OF TECHNOLOGY, Department of Mechanics and Mechanical and Aerospace Engineering, Chicago, Ill. 60616. Dr. Sudhir Kumar, Chairman.

052-07341-010-50

V/STOL ORIENTED AERODYNAMIC STUDIES

(*b*) NASA.
(*c*) Dr. F. Lavan, Dr. T. P. Torda, T. A. Morel.
(*d*) Analytical.
(*e*) Development of a turbulent wall jet calculation program. Necessary first step is the development of a new approach to calculation of free turbulent shear flows (using turbulent kinetic energy equation).
(*f*) First part completed in Aug. 1972.
(*h*) Presented at the *Langley Working Conference on Free Turbulent Shear Flows*, July 1972.

IIT RESEARCH INSTITUTE, Mechanics Research Division, 10 W. 35th Street, Chicago, Ill. 60616. Dr. K. E. McKee, Director.

053-08586-020-50

DETERMINATION OF SOUND SOURCE INTENSITIES IN SUBSONIC AND SUPERSONIC JETS

(*b*) NASA George C. Marshall Space Flight Center.
(*c*) Dr. R. J. Damkevala.
(*d*) Experimental and applied research.
(*e*) The optical crossed-beam correlation technique was employed for measurement of area integrals of turbulence parameters contributing to sound production in air jets. Source strength distributions were estimated from these measurements which will be compared with direct measurements with an elliptical acoustic mirror microphone system.
(*h*) **Statistical Properties of Turbulent Density Fluctuations,** L. N. Wilson, R. J. Damkevala, *J. Fluid Mech.* **43,** 2, pp. 291-303, 1970.
Turbulence Measurements with an Infrared Crossed Beam System Near 4.3 Microns, R. J. Damkevala, K. A. Kadrmas, *AIAA 8th Aerospace Sciences Mtg., Paper No. 70-235*, Jan. 1970.

053-08587-720-44

DESIGN HIGH PRESSURE WATER CIRCULATION SYSTEM FOR INSTRUMENTATION ENVIRONMENTAL TESTING

(*b*) National Oceanographic Instrumentaion Center, Dept. of Commerce, Washington, D.C.
(*c*) W. J. Courtney.

(*d*) Critical design of thermally controlled–pressure controlled salt water environemtal system.
(*e*) A high pressure thermally controlled system (0.05 percent control on pressure; 0.01°C control on temperature) is being developed. Advanced thermal and pressure control techniques are needed. Flow pattern through the chamber must be determined so that isothermal conditions are approached while water is flowing at 50 gpm.

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ILLINOIS, STATE OF, Department of Transportation, Office of Water Resource Management, 201 West Monroe Street, Springfield, Ill. 62706. Mr. John C. Guillou, Chief Waterway Engineer.

054-01863-410-00

EROSION CONTROL, ILLINOIS SHORE OF LAKE MICHIGAN

(*b*) State of Illinois.
(*d*) Field investigation; applied research.
(*e*) Obtain and correlate basic data on the several forces and factors involved in erosion processes along the Illinois shore of Lake Michigan to the end that future efforts toward the prevention of erosion might be founded upon a more definite and factual basis with a consequent greater degree of assurance that the works will serve the intended purpose.
(*f*) Discontinued.

054-05549-300-00

ILLINOIS RIVER

(*b*) State of Illinois.
(*d*) Experimental; applied research.
(*e*) A hydraulic model study is being conducted to determine the effects, on the upper Illinois River, of various flood relief measures proposed for the Illinois Waterway and Chicago Sanitary and Ship Canal.
(*g*) Results of first test program based on existing river system are completed.

054-05656-350-00

KINKAID CREEK DAM

(*b*) State of Illinois.
(*d*) Experimental; applied research.
(*e*) A hydraulic model study was conducted to assist in the design of the spillway and stilling basin for a proposed reservoir to be constructed in Jackson County, Ill.
(*f*) Completed.
(*g*) Report of results submitted; concerns hydraulic performance of spillway and volume of natural plunge pool.

054-06094-350-00

NAPERVILLE DAM

(*b*) State of Illinois.
(*d*) Experiment; applied research.
(*e*) A hydraulic model study was conducted to assist in the design of the outlet structure and stilling basin for a proposed reservoir to be constructed near Naperville, Ill., in DuPage County.
(*f*) Completed.
(*g*) Report of results submitted; concerns performance of spillway structure and stilling basin.

054-06095-330-00

MONTGOMERY LOCK

(*b*) State of Illinois.
(*d*) Experimental; applied research.
(*e*) A hydraulic model study was conducted to determine the filling system for the proposed recreational navigation locks to be constructed in the Fox River at Montgomery, Ill.
(*f*) Completed.
(*g*) Reports submitted on two-lock system having a common filling wall, and end-to-end two-lock configuration.

054-08022-300-00

OPEN CHANNEL CONSTRICTIONS

(*b*) State of Illinois.
(*d*) Experimental; basic research.
(*e*) In conjunction with a constricted reach of the Illinois River, a hydraulic model investigation was conducted on a rectangular, prismatic open channel of adjustable slope using a trapezoidal constriction of varying dimensions to determine the effect on the backwater of the geometry characteristics of the constriction, namely, the percentage constriction, constriction length, entrance angle and exit angle.
(*g*) Some partial results.

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ILLINOIS STATE WATER SURVEY, Box 232, Urbana, Ill. 61801. William C. Ackermann, Chief. (A list of publications is available upon request from Illinois State Water Survey.)

055-07331-860-65

HYDRAULICS OF WATER TREATMENT PLANTS

(*b*) Chicago Water Filtration Plant.
(*c*) Mr. H. W. Humphreys.
(*d*) Experimental; applied research.
(*e*) Improve the flow conditions in the various components of a water treatment plant. The first project is a model study to improve the flow conditions in a settling basin. Model modifications will be made, the flow conditions observed, and velocity distributions measured to determine which modification is desirable to improve the flow conditions.
(*g*) An experimental model of a settling basin is under construction. Development of a velocity meter capable of measuring small velocities is under way.

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UNIVERSITY OF ILLINOIS, COLLEGE OF AGRICULTURE, Department of Agricultural Engineering, Urbana, Ill. 61801. Professor Benjamin A. Jones, Jr.

056-0008W-810-00

RUNOFF FROM SMALL AGRICULTURAL AREAS IN ILLINOIS

For summary see Water Resources Research Catalog **6**, 2.0638.

(*h*) *Clodhopper* **Helps with Soil Studies,** J. K. Mitchell, B.A. Jones, Jr., *Ill. Res.* **13**, 4, pp. 10-11, 1971.

056-0009W-810-00

LABORATORY MODEL STUDIES OF CONSERVATION AND DRAINAGE STRUCTURES

For summary see Water Resources Research Catalog **6**, 8.0296.

(*h*) **Effect of a Soil Conditioner on Hydraulic Conductivity and Soil Stability,** F. F. Walter, *M.S. Thesis*, Univ. of Ill. at Urbana Library, 1970.
A Model Study of Drain Envelopes in a Coarse Base Silt Material, W. D. Lembke, E. A. Bucks, *Trans. Am. Soc. Agric. Eng.* **13**, 5, pp. 669-671, 675, 1970.
Drop Size and Impact Velocity Effects on the Detachment of Soils Under Simulated Rainfall, G. D. Bubenzer, B. A. Jones, Jr., *Trans. ASAE* **14**, 4, pp. 625-628, 1971.

517-020 O-LT - 74 - 4

056-0010W-810-00

HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS

For summary see Water Resources Research Catalog **6**, 2.0639.

(*h*) **Multi-Dimensional Irrigated Water Balance for Humid Areas, A Computer Model,** R. J. Godwin, *M.S. Thesis*, Univ. of Ill. at Urbana Library, 1970.
Soils Surface Depression Storage Calculated by Geometrical Models, N. A. Barron, *M.S. Thesis*, Univ. of Ill. at Urbana Library, 1970.
Non-Linear Response of a Small Drainage Basin Model, R. A. Rastogi, B. A. Jones, Jr., *J. Hydrology* **14,** 1, pp. 29-42, 1971.
Design Irrigation Pumping Rates in a Humid Region, R. J. Godwin, W. D. Lembke, B. A. Jones, Jr., *Trans. ASAE* **14,** 5, pp. 575-878, 882, 1971.

056-0154W-840-00

NITRATE REDUCTION IN THE VICINITY OF TILE DRAINS

For summary see Water Resources Research Catalog **6**, 5.0478.

056-04987-840-00

THE EFFECT OF GYPSUM AND DRAINAGE ON SOLONETZIC SOILS (SLICK-SPOTS) IN ILLINOIS

(*b*) In cooperation with Dept. of Agronomy.
(*d*) Experimental field investigation.
(*e*) To test the feasibility of replacing and removing excess sodium from solonetzic soils under field conditions with different methods and rates of applying gypsum (calcium sulphate), different degrees of disturbing the subsoil, and different spacings of tile drains. Twenty plots were established in a random pattern to compare 3 positions for the application of gypsum and 3 spacings of tile drains with check plots. The tile effluent is measured by recording equipment to determine the rate and volume of flow. Also samples will be taken to determine the amount of sodium in the leachate.
(*g*) Corn yields have increased as a result of the application of gypsum and tile drainage.
(*h*) **Gypsum Improves Corn Yield and Sodium Removal in Natric Soils,** J. B. Fehrenbacher, H. J. Kleiss, A. K. Sharma, B. A. Jones, Jr., *Ill. Res.* **14,** 2, pp. 3-4, 1972.

056-08024-820-00

NITROGEN AS AN ENVIRONMENTAL QUALITY FACTOR–DETERMINING AND MODELING THE VARIOUS STEPS OF THE N CYCLE

(*b*) Environmental Quality Council, Agric. Exp. Sta., Univ. of Illinois.
(*d*) Field and laboratory investigation; basic research.
(*e*) An interdisciplinary study to determine and model, by using field and analytical procedures, the accuracy with which the amounts of nitrogen can be predicted in various steps of the nitrogen cycle. The initial phase is an intensive study of the sources and movement of nitrates into shallow wells located in the claypan area of Illinois.

UNIVERSITY OF ILLINOIS, Hydrosystems Laboratory, Department of Civil Engineering, Urbana, Ill. 61801. Professor V. T. Chow.

057-04543-800-33

WATER RESOURCES SYSTEM ANALYSIS

(*b*) Office of Water Resources Research and Dept. of Civil Engineering.
(*d*) Theoretical; applied research.
(*e*) A supply and demand water resources system model is developed which consists of surface and subsurface reservoirs and the demands for hydropower, irrigation and flood control. The model is optimized by differential dynamic programming for obtaining *near optimum* scales of development of the water resources system. The model so developed can be extended to simulating more complicated water resources systems. Based on Bellman's recursive equation of dynamic programming, a discrete differential dynamic programming has been developed, which considers the optimization of the system operation in the neighborhood of a set of trial state trajectories, employing a specific set of initial and final states. The merits of the proposed approach are demonstrated through its application to two multiple-unit, multiple-purpose water resources systems. The analysis is performed using deterministic inflows in order to save computer time.
(*g*) The model has been developed and tested for constant and variable inputs.
(*h*) **The Discrete Differential Dynamic Programming Approach to Water Resources Systems Optimization,** M. Heidari, V. T. Chow, P. V. Kokotovic, D. D. Meredith, *Water Resour. Res.* **7,** 2, pp. 273-282.

057-05657-810-00

HYDROLOGIC ANALYSIS BY ANALOG COMPUTERS

(*d*) Applied research.
(*e*) Direct and indirect analog computers are used for the analysis of hydrologic problems on surface and ground water. In the analysis of surface water problems, the EAL PACE computer of the Analog Computer Laboratory was employed to route floods through linear as well as nonlinear reservoirs. For the analysis of ground water, resistance networks were designed and analyzed for a number of groundwater regions. The results will be recommended for use in the design and planning of water resources systems.
(*f*) Inactive.

057-07335-810-33

METHODOLOGIES FOR FLOW PREDICTION IN URBAN STORM DRAINAGE SYSTEMS

(*b*) Office of Water Resources Research.
(*c*) Professor B. C. Yen.
(*d*) Theoretical and experimental; applied research.
(*e*) Study involves theoretical and experimental investigations directed to determine flow of storm water in urban drainage systems. The urban drainage system is considered as an integrated system of components of urban surface, gutters, inlets, sewer branches, junctions, manholes, and other structures. Modern concepts in hydrology, fluid mechanics, and systems engineering are utilized to develop methods for quantitative prediction of storm runoff at various locations in an urban drainage system. Particular emphasis is given to the effects of urbanization, effects of inlets and junctions on the flow in the system, the interrelationship among the components and the possibility of optimization of the composition of the components. The risks involved in the hydraulic design are also studied.
(*h*) **Risks Analysis in Design of Hydraulic Projects,** B. C. Yen, A. H.-S. Ang, *Stochastic Hydraulics*, Univ. of Pittsburgh, 1971, pp. 694-709.
Spatially Varied Open-Channel Flow Equations, B. C. Yen, *Water Resour. Center Res. Rept. No. 51*, Univ. of Ill., Dec. 1971.

057-07336-810-33

STUDY OF THE HYDROLOGY FOR MODELS OF THE GREAT LAKES

(*b*) Office of Water Resources Research.
(*c*) Professor D. D. Meredith.
(*d*) Analytical; applied research.
(*e*) A monthly water budget was developed for each lake in the Great Lakes system for calendar years 1946 through 1965. The water budget for a lake consists of the

precipitation on the lake surface, the evaporation from the lake surface, the runoff into the lake from the surrounding land area, the inflow to the lake, and the outflow from the lake.

(*h*) **Monthly Precipitation Charts for the Great Lakes Basin,** D. M. A. Jones, G. E. Stout, *12th Conf. on Great Lakes Research*, 1969.

057-07337-810-54

HYDRODYNAMICS OF WATERSHED FLOW

(*b*) National Science Foundation.
(*d*) Theoretical and experimental; applied research.
(*e*) Research aims to apply the mathematical models developed in a previous NSF project on mechanics of surface runoff, with the experimental verification by the Univ. of Ill. Watershed Experimentation System (WES), to practical problems such as flood control and urban drainage in the field of watershed hydraulics. The models are Illinois Hydrodynamic Watershed Models II and III. The two models, respectively of one-dimension and two-dimension, consist of a set of partial differential equations with appropriately prescribed initial and boundary conditions and with Darcy-Weisbach friction coefficient as measure of watershed roughness. They are normalized and solved on specified grid schemes by digital computer. The WES is an instrumental system which can produce an artificial storm on the laboratory drainage basin to test the mathematical models. During the year, WES was repaired and improved with the design and construction of additional operating power and special constant outflow measuring device. The computer algorithms were also extended. In addition, a two-dimensional WES was designed and is being constructed in the new Hydrosystems Laboratory.
(*h*) **Role of WES in the Development of Hydrodynamic Watershed Model,** V. T. Chow, *Proc. Intl. Symp. on Mathematical Models in Hydrology* 2, 2, Topic 5, pp. 1-14, Warsaw, Poland, July 1971.
Physical Evaluation of Watershed Modeling by Hydrodynamic Equations of Motion, V. T. Chow, *Proc. Symp. on Mathematical Models in Geophysics*, Intl. Union Geodesy and Geophys., General Assembly of Moscow, Aug. 1971, pp. 1-13.
Formulation of Mathematical Watershed-Flow Model, C. L. Chen, V. T. Chow, *J. Engrg. Mech. Div., Proc. ASCE* **97,** EM3, June 1971, pp. 809-828.
Computer Solution of a Hydrodynamic Watershed Model (IHW Model II), S. J. Kareliotis, V. T. Chow, *Civil Engrg. Studies, Hydraulic Engrg. Series No. 25*, Dept. of Civil Engrg., Univ. of Illinois-Urbana, Mar. 1971, 128 pp.

057-07338-800-33

ADVANCED METHODOLOGIES FOR WATER RESOURCES PLANNING

(*b*) Office of Water Resources Research.
(*c*) Professors V. T. Chow and D. D. Meredith.
(*d*) Theoretical; applied research.
(*e*) Investigate advanced techniques of water resources planning which have not been generally introduced into practice. These techniques include mainly various methods of operations research such as stochastic analysis and dynamic programming. In the investigation mathematical models are formulated for computer analysis and actual river basin data are tested in working procedures to be developed. The procedure of investigation consists of three steps: (1) to critically examine the feasibility of the concepts of stochastic hydrology and various optimization techniques, (2) to formulate hydroeconomic system models for analysis by stochastic optimization techniques, and (3) to develop working procedures using optimization techniques for application to practical water resources planning. During the year a farm irrigation system model has been developed.
(*h*) **Methodologies for Water Resources Planning: DDDP and MLOM (TLOM),** V. T. Chow, *Water Resour. Center, Univ. of Ill.-Urbana, Res. Rept. No. 47, UILU-WRC-71-0047*, Nov. 1971, 50 pp.

057-07339-810-33

STOCHASTIC ANALYSIS OF HYDROLOGIC SYSTEMS

(*b*) Office of Water Resources Research.
(*d*) Theoretical; applied research.
(*e*) Develop a practical procedure by which the stochastic behavior of a hydrologic system can be adequately simulated. In the study a watershed is treated as the stochastic hydrologic system whose components are simulated by time series models. Emphasis is given to application of the procedure to the planning of rural and urban watersheds in Illinois. The hydrologic system model is formulated on the basis of conservation of mass, and composed of input, output and throughput stochastic processes. The time series models are selected by means of correlograms and spectral analysis. To demonstrate the practical application of the method of analysis so developed, the upper Sangamon River basin above Monticello in east central Illinois is used as the sample watershed. Another model using transition probability matrixes was also investigated, and the residual stochastic process of a hydrologic system model was analyzed. Work has also been started on a multiple-input model.
(*h*) **Stochastic Hydrologic Systems,** V. T. Chow, *Proc. U.S.-Japan Bi-Lateral Seminar in Hydrology*, Honolulu, Jan. 1971, Water Resources Publications, Ft. Collins, Colo., 1971, pp. 1.1-1.19.
Discussion on Stochastic Hydrologic Systems, V. T. Chow, *Proc. U.S.-Japan Bi-Lateral Seminar in Hydrology*, Honolulu, Jan. 1971, Water Resources Publications, Ft. Collins, Colo., 1971, pp. 1.22-1.23.
Stochastic Analysis of Hydrologic Systems, V. T. Chow, *Proc. 14th Cong. Intl. Assoc. Hydraul. Res.* **5,** Aug.-Sept. 1971, Paris, France, pp. 265-271.
Stochastic Approach in Hydraulics, V. T. Chow, *Hydraulic Engrg., Chinese Inst. of Hydraulic Engrs.* **13,** Nov. 1971, pp. 1-5.
Stochastic Hydraulics–A Challenging Field of Study, V. T. Chow, in *Stochastic Hydraulics, Proc. 1st Intl. Symp. on Stochastic Hydraulics*, Pittsburgh, Pa., May-June 1971, pp. 3-8.
Reply to Comments on Analysis of Stochastic Hydrologic Systems, V. T. Chow, S. J. Kareliotis, *Water Resour. Res.* **8,** 1, Feb. 1972, pp. 163-165.

057-07340-310-00

EVALUATION OF FLOOD RISKS

(*d*) Theoretical; applied research.
(*e*) Flood data at ten stream gaging stations on rivers in Illinois are analyzed for their characteristics of flood generation on the basis of the theory of nonparametric probability distributions. Once the probability model for flood occurrences is formulated, flood sequences are generated by the Monte Carlo method and then compared with historical flood sequences.

057-08025-810-33

HYDROLOGIC MODELS OF THE GREAT LAKES

(*b*) Office of Water Resources Research.
(*c*) Professor D. D. Meredith.
(*d*) Analytical; applied research.
(*e*) Develop and analyze deterministic and stochastic hydrologic models for each of the Great Lakes and the Great Lakes as a system. The monthly precipitation on the lake surface, evaporation from the lake surface, and runoff into the lake from the surrounding land area for calendar years 1946 through 1965 are being used to develop the models.

057-08026-710-54

TRACER MIXING FOR DISCHARGE MEASUREMENTS IN PIPES

(*b*) National Science Foundation.
(*c*) Professor E. R. Holley.
(*d*) Theoretical; experimental; applied research.
(*e*) The enhancement of mixing which can be achieved using various types, velocities, and orientations of injections will be studied, with emphasis given to injections made near the pipe wall. The influence of using a buoyant tracer to increase mixing will also be studied, as will the effects of pipe bends on tracer mixing.

057-08027-700-33

DEVELOPMENT OF A DEVICE FOR DISCHARGE MEASUREMENT WITHIN A SEWER PIPE

(*b*) Office of Water Resources Research.
(*c*) Professor H. G. Wenzel.
(*d*) Experimental; applied research.
(*e*) Develop a device which is capable of measuring unsteady discharge within a sewer pipe under both open-channel and full-flow conditions. Analytical studies will be carried out to determine the optimum geometry and theoretical rating curves. These results will then be investigated experimentally. Characteristics such as head loss, backwater effects, and reduction in sewer capacity will be studied. Actual rating curves will be developed using various pipe sizes and final recommendations for design presented.

057-08028-200-00

OPEN-CHANNEL FLOW IN BENDS

(*c*) Professor B. C. Yen.
(*d*) Theoretical research.
(*e*) Characteristics of subcritical open-channel flows in bends are investigated analytically. Particular emphasis is given to the effects of the spiral motion. Both laminar and turbulent cases are studied.
(*h*) **Spiral Motion of Developed Flow in Wide Curved Open Channels,** B. C. Yen, *Chap. 22*, *Sedimentation*, Ft. Collins, Colo., pp. 22.1-22.33, 1972.

057-08029-060-61

MIXING CHARACTERISTICS OF HEATED SURFACE DISCHARGES

(*b*) Water Resources Center.
(*c*) Professors E. R. Holley and W. H. C. Maxwell.
(*d*) Theoretical; experimental research.
(*e*) Development of laboratory apparatus and instrumentation to study problems of discharges of heated water into bodies of water with various boundary configuration. Initially the apparatus is to be used to study thermal wedges established at the surface of an open channel flow with data to be collected on temperature distributions and velocity distributions with a view to obtaining detailed information on shear stresses at the interface between heated and unheated water.

057-08030-860-00

OPTIMAL OPERATION OF RESERVOIRS

(*d*) Theoretical; applied research.
(*e*) Operations research techniques are used to optimize the operation of a system of reservoirs. The procedure so developed is used to determine operating policies for existing reservoir systems or for potential system designs in connection with simulation studies. An actual flood control system located in the Upper Wabash River Basin in Indiana is used as an illustrative example.
(*h*) **General Report on Optimal Operation of Water Resources Systems,** V. T. Chow, *Proc. Intl. Symp. on Mathematical Models in Hydrology*, Warsaw, Poland, July 1971, pp. 1-9.

057-08031-800-33

ADVANCED METHODOLOGIES FOR WATER RESOURCES PLANNING–PHASE II

(*b*) Office of Water Resources Research.
(*d*) Theoretical; applied research.
(*e*) Refine the new methodologies that have been developed in Phase I of the research program, to develop additional new water resources planning tools, and to perform sensitivity tests for proposed or existing water resources projects by means of the new planning tools so developed in order to examine the system responses due to hydrologic, economic urban and other factors affecting water resources problems. The proposed research proceeds in two stages. The first stage is to refine the DDDP technique for variable width of its *corridor* and for its conjunctive use with the successive dynamic programming technique in order to achieve maximum efficiency of utilization. The second stage is devoted to investigate new water resources problems such as water quality control and urban water development, and then to apply the new DDDP and MLOM techniques to these models.
(*h*) **Model for Farm Irrigation in Humid Areas,** J. S. Windsor, V. T. Chow, *J. Irrig. and Drain. Div.*, *Proc. ASCE* **97,** IR3, Sept. 1971, pp. 369-385.

057-08032-810-00

MODELING OF HYDROLOGIC SYSTEMS

(*d*) Theoretical; applied research.
(*e*) A lumped, deterministic, nonlinear mathematical model proposed for the simulation of hydrologic systems is developed from expansion of a general storage function of input and output in Taylor's series about a steady state. The model recommended for practical application is based on the system model in the form of a third-order differential equation, the coefficients of which are considered as functions of the peak discharge of direct runoff. In the analysis of the model, watershed is taken as the hydrologic system. Nine watersheds with more than 70 major and minor storms were used in the analysis and verification of the recommended model. The results indicate a very satisfactory simulation of watershed hydrologic systems by the model.
(*h*) **General Hydrologic System Model,** V. T. Chow, V. C. Kulaidaiswamy, *J. Hydraul. Div.*, *Proc. ASCE* **97,** HY6, June 1971, pp. 791-804.

057-08033-310-00

EVALUATION OF TIME LAG OF FLOOD FLOWS

(*d*) Theoretical research.
(*e*) The time lag of flood flows is an important characteristic of the hydrologic behavior of watersheds. In this study, the time lag is taken as the time of occurrence of the flood peak since the flood began. A large number of historical floods on small watersheds in Illinois were analyzed. The result has shown that the time lag bears a unique relationship with the size of the drainage area. A mathematical model for this relationship was investigated.

UNIVERSITY OF ILLINOIS, Fluid Mechanics and Hydraulics Laboratory, Department of Theoretical and Applied Mechanics, Urbana, Ill. 61801. Professor R. T. Shield, Department Head. Professor J. M. Robertson, Area Coordinator for Fluids.

058-02536-020-00

STUDY OF HOMOLOGOUS TURBULENCE

(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic research.
(*e*) The nature of turbulence (its production and dissipation) is being studied in the simplest possible shear flow-plane

Couette flow where the shear is constant and the turbulence homogeneous but not isotropic. Mean-flow studies essentially complete.
(*f*) Suspended.
(*h*) **Turbulence in Plane Couette Flow,** J. M. Robertson, H. F. Johnson, *J. Eng. Mech. Div., Proc. ASCE* **96,** EM6, 1970, pp. 1171-1182.

058-04142-010-00

TURBULENT BOUNDARY-LAYER FLOW TOWARDS A NORMAL STEP

(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic research.
(*e*) An analytical and experimental study is being made of upstream separation, i.e., the real fluid behavior (separation, mixing, reattachment) in front of a normal step projecting inward from a plate along which fluid is flowing with a turbulent boundary layer. Analysis based on frozen-vorticity flow model.
(*f*) Suspended.
(*g*) First phases of study completed; in one case rather good agreement was found between theoretical solution and experimental observation of separation streamline.
(*h*) **Turbulent Separation Analysis Ahead of a Step,** D. B. Taulbee, J. M. Robertson, *ASME Paper 71-WA/FE-32*, publication pending in *J. Basic Eng., ASME*, 1972.

058-04143-270-60

APPLICATION OF FLUID MECHANICS PRINCIPLES TO ANALYSIS OF PATHOLOGICAL CHANGES IN THE CEREBRAL CIRCULATION

(*b*) Department of Mental Health, State of Illinois.
(*c*) Prof. M. E. Clark, Talbot Laboratory.
(*d*) Basic research; experimental and numerical.
(*e*) The flow of blood in the Circle of Willis–the arterial distribution system for the brain–is studied utilizing digital computer and electrical analog models. Present goal is to fabricate models which will simulate the prototype characteristics of unsteady flow and flexible vessels.
(*g*) An important medical area much in need of information is the one concerned with the circulation of blood in the brain and with the factors which control this circulation in the normal individual and in one who suffers from arteriosclerosis, stroke, or similar conditions. This project will expand our knowledge in this area by comparing blood flow and blood pressure distributions obtained from computer models and from the living animal under normal and pathological conditions. Three models based on different engineering methods will be derived, compared with each other, and compared with the living animal. The development of a successful working model will provide generalized concepts usable by physicians and surgeons in their treatment of patients.
(*h*) **Cerebral Blood Flow Comparisons between Model and Prototype,** W. A. Himwich, M. E. Clark, *J. Appl. Physiology* **31,** Dec. 1971.

058-05778-030-00

BODY FLOWS AT LOW REYNOLDS NUMBERS

(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic analytical and experimental research.
(*e*) Except for flat plate, analytical flow and drag relations are available only in the creeping motion and boundary layer regimes. Experimental data is available only for a few other bodies in the intermediate (Navier-Stokes) range. Objective of study is to help fill this gap. Current effort concerns flow occurrence very near leading edge of wedges.
(*h*) **An Analysis of the Viscous Flow Past a Circular Cylinder Using Coordinate Expansions,** T. J. Kim, L. K. Shirely, J. M. Robertson, *ZAMM* **51,** 1971, pp. 235-236.

058-06139-010-00

LONGITUDINAL CURVATURE EFFECTS ON TURBULENT BOUNDARY LAYER

(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic; experimental and analytical.
(*e*) Boundary curvature in flow direction causing pressure difference between wall and edge of layer is known to affect laminar boundary layer and there is some suggestion of its effect on turbulent layers. Flow of a turbulent layer at several thicknesses along a circular surface is being studied to evaluate the occurrences.

058-06141-210-00

VAPOR FORMATION DURING WATERHAMMER

(*c*) Professors C. E. Bowman and J. M. Robertson, Talbot Laboratory.
(*d*) Basic analytical and experimental research.
(*e*) To study bubble formation during pressure transients in water filled pipeline. Appearance of voids and their effect on wave propagation after valve closure is studied.
(*g*) The pressure-time history of waterhammer accompanied by bubble formation was found identical with usual prediction for the first, second, and third passages of pressure wave. Celerity of fourth pressure wave is found to depend on quality of the water bubble mixture. Experiments with various amounts of cavitational occurrence have been conducted.

058-6143-270-88

ABNORMALITY DETECTION IN THE CEREBRAL CIRCULATION VIA FLUID IMPEDANCE CHANGES

(*b*) St. Paul-Ramsey Hospital, St. Paul, Minn.
(*c*) Professor M. E. Clark, Talbot Laboratory.
(*d*) Experimental and theoretical; applied research.
(*e*) Diagnostic investigations of the cerebral circulation would be enhanced if not only the presence of system abnormalities but their severity and clinical significance could be evaluated. Such abnormalities give rise to pressure and flow reflections and, since fluid impedance relates pulsatile pressure to flow, changes in impedance can be used to detect and evaluate their presence. Experimental and computer models of systems containing stenoses, aneurysms, and other discontinuities have been studied and recognition patterns have been developed from impedance results. Current research aimed at similar work on experimental animals using artificial modifications of large easily accessible systemic arteries and the cerebral arteries themselves.
(*h*) **The Use of Fluid Impedance as a Disorder Detector in Computerized Arterial Systems,** G. F. Ayala, M. E. Clark, *Summer Computer Simulation Conf.*, July 1971, Boston, Mass.

058-07351-010-00

TURBULENT BOUNDARY LAYER FLOW ON FLAT PLATE

(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic research; experimental and review of literature.
(*e*) Refurbishing of theory for layer, assessment of transition occurrences in terms of leading edge, stream turbulence level and roughness or trips; a second phase concerns effect of high stream turbulence level on a turbulent layer.
(*f*) Experiments continue on first phase.
(*h*) **Stream Turbulence Effects on Turbulent Boundary Layer,** J. M. Robertson, C. F. Holt, publication pending in *J. Hydr. Div., Proc. ASCE*, 1972.

058-07352-120-00

FORCES ON BODIES IN NON-NEWTONIAN FLUIDS

(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic research; also Ph.D. thesis.

(*e*) Nature of body-force relations (particularly drag) for bodies in relative motion with fluids such as Bingham plastics. Experiments have been carried out with clay-water mixtures (and on their viscometry) and are planned for other fluids. Analytical work on extending theoretical formulations.

(*h*) **Fluid-Dynamic Consideration of Bottom Materials,** H. Pazwash, J. M. Robertson, *J. Hydr. Div., Proc. ASCE* **97,** HY9, 1971, pp. 1317-1329.
Forces on Bodies in Bottom-Like Materials, J. M. Robertson, H. Pazwash, *Ocean Eng.* **2,** 1971, pp. 75-81.

058-07353-630-70

NOISE PRODUCTION IN FLUID-POWER SYSTEMS

(*b*) Sundstrand Aviation.
(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic research, analytical in nature with experiments planned.
(*e*) The manner of noise generation by pressure transients in the cylinders of positive-displacement pumps is being studied via analysis and analog experiments (water table) of wave motions.
(*h*) **Water Table Use in Studies of Pressure Waves in Fluid-Power Systems,** C. F. Holt, T. J. Labus, J. M. Robertson, *TAM Report 339*, 1971.

058-07354-210-40

CALCULATIONS FOR OSCILLATORY FLOW IN A RIGID PIPE

(*b*) Public Health Service, NIH.
(*c*) Professor M. E. Clark, Talbot Laboratory.
(*d*) Basic research–numerical.
(*e*) Numerical finite difference solutions to oscillatory flow in plane two-dimensional and axisymmetric conduits are being developed to assess the suitability of both explicit, implicit and matrix procedures, establish the computational stability criteria, and determine the time required to reach steady state.

058-07355-000-88

NUMERICAL ANALYSIS OF LAMINAR OSCILLATORY NAVIER-STOKES FLOWS PAST TWO-DIMENSIONAL AND AXISYMMETRIC HUMPS

(*b*) Interscience Res. Inst., Champaign, Ill.
(*c*) Professor M. E. Clark, Talbot Laboratory.
(*d*) Theoretical and experimental research.
(*e*) Fluid dynamic occurrences in simple conduits for flows through various types of geometric barriers are being theoretically and experimentally correlated for comparison with hemodynamic occurrences in similar physiological situations. This research attempts to develop the analysis by finite difference solution of the appropriate Navier-Stokes equations for pressure, shear and vorticity.
(*g*) Some preliminary results for square jumps in the plane case have been achieved at low and moderate values of the oscillatory flow parameter $D(f/\nu)^{\cdot}$ (D is the plate spacing, f frequency of oscillation, and ν the kinematic viscosity of fluid) and over the lower end of the physiological range of the Karman number $MD^3/\rho\nu^2$ (ρ is fluid density and M is amplitude of driving pressure gradient).
(*h*) **Numerical Calculations of Oscillating Flow in the Vicinity of Square Wall Obstacles in Plane Conduits,** L. C. Cheng, M. E. Clark, J. M. Robertson, *J. Biomechanics*, in press.

058-08034-110-00

LIQUID-METAL PIPE FLOWS WITH STRONG MAGNETIC FIELDS

(*c*) Professor J. S. Walker, Talbot Laboratory.
(*d*) Theoretical.
(*e*) The flow of a liquid metal in a variable-area duct (either diverging or converging) with a strong transverse magnetic field is being treated with the method of matched asymptotic expansions.
(*h*) **Three-Dimensional MHD Duct Flows With Strong Transverse Magnetic Fields. Part 2. Variable-Area Rectangular Ducts With Conducting Sides,** J. S. Walker, G. S. S. Ludford, J. C. R. Hunt, *J. Fluid Mech.* **46,** 1971, pp. 657-684.

058-08035-130-00

FLUID CONVEYANCE OF PARTICLES IN VERTICAL PIPES

(*c*) Professor J. M. Robertson, Talbot Laboratory.
(*d*) Basic research; student project.
(*f*) Initial studies underway of water flow with 1/2-inch glass spheres in 3-inch pipe. This research attempts to develop the analysis by finite difference solution of the appropriate Navier-Stokes

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UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE, Department of Energy Engineering, College of Engineering, Box 4348, Chicago, Ill. 60680. J. P. Hartnett, Department Head.

060-07349-270-00

EFFECTS OF IRREGULAR GEOMETRIES AND OSCILLATORY MOTION UPON BLOOD OXYGENATION

(*c*) Professor Joseph C. F. Chow, Ph.D.
(*e*) Flow problem inside an axisymmetric wavy channel to find effects of width and shape of channel on oxygen transport.

060-07350-020-00

A SIMPLIFIED STATISTICAL THEORY OF TURBULENT, CHEMICALLY REACTING SHEAR FLOWS

(*c*) Professor Paul M. Chung, Ph.D.
(*e*) Analysis of mixing and chemical reactions, particularly combustion taking place in turbulent shear flow fields, and chemical laser applications.

060-08588-010-00

LAMINAR IGNITION ACCORDING TO SINGULAR PERTURBATION

(*c*) Professor Paul M. Chung, Ph.D.
(*e*) Description of mathematical singular surface which controls the ignition criteria of laminar boundary layers.

060-08589-860-00

ALGAE GROWTH IN CONTAMINATED WATER

(*c*) Professor Paul M. Chung, Ph.D.
(*e*) Mathematical description of fluctuation of the algae population as affected by the concentrations of oxygen, neutrion, etc., in turbulent stratified fluid.

060-08590-250-00

TURBULENT SHEAR REDUCTION BY INJECTION OF TRACE POLYMERS

(*c*) Professor Paul M. Chung, Ph.D.
(*e*) Study of energy exchange between the turbulence energy and the vibrational energies of polymer molecules which results in the suppression of turbulence and increase of the laminar sublayer thickness.

060-08592-870-00

THE ATMOSPHERE AS A SOURCE OF LEAD CONTAMINATION IN LAKE MICHIGAN

(*c*) Professor A. C. Cogley, Ph.D.
(*e*) Determining the amount of lead that enters Lake Michigan by aerosol washout.

060-08593-870-00

INTERDISCIPLINARY STUDIES OF MANMADE AEROSOL LIFE CYCLES

(*c*) Professor A. C. Cogley, Ph.D.
(*e*) Determining the life cycles of aerosols found in the Chicago urban atmosphere, including the source, transport, and sink. Also the study of biological interaction with these aerosols.

060-08594-140-00

MASS TRANSFER COOLING STUDIES

(*c*) Professor J. P. Hartnett, Ph.D., Head, Dept. of Energy Engrg.
(*e*) Study of heat transfer in the presence of mass transfer including turbulent flow over a flat plate and in well-defined pressure gradient situations. The main stream gas is air while a secondary gas may be air or a foreign gas such as nitrogen or helium.

060-08595-120-00

HEAT TRANSFER IN VISCOELASTIC FLUIDS

(*c*) Professor J. P. Hartnett, Ph.D., Head, Dept. of Energy Engrg.
(*e*) General research involving characteristics of viscoelastic fluids, measure of conductivity of such fluids, and heat transfer associated with flow over a flat plate, circular cylinders and other geometries of importance.

060-08596-490-00

INVESTIGATION INTO THE STRUCTURE AND DYNAMICS OF TORNADOES

(*c*) Professor Kenneth L. Uherka, Ph.D.
(*e*) Theoretical modeling of a tornado vortex and its interaction with surface structures.

060-08597-870-00

RESEARCH AND TRAINING PROGRAM IN URBAN TRANSPORTATION

(*c*) Professor Kenneth L. Uherka, Ph.D.
(*e*) Mathematical modeling of environmental air pollution due to urban transportation. Development of dynamic diffusion models.

060-08598-010-00

MODELING ATMOSPHERIC FLOWS

(*c*) Professor Calvin J. Wolf, Ph.D.
(*e*) The development of laboratory methods for experimental models of the atmospheric boundary layer.

060-08599-020-00

TURBULENT BOUNDARY LAYER WITH LARGE SCALE ROUGHNESS

(*c*) Professor Calvin J. Wolf, Ph.D.
(*e*) An experimental determination of the response of a turbulent boundary layer to wall protuberances having heights of the order of the boundary layer thickness with small aspect ratios.

INDIANA, STATE OF, Surface Water Section, Division of Water, Department of Natural Resources, State Office Building, Indianapolis, Ind. 46204. Dr. Ramanand Prasad, Section Head.

061-07356-810-00

FREQUENCY ANALYSIS OF HYDROLOGIC INFORMATION

(*d*) Applied research.
(*e*) A comparative study of various methods of hydrologic frequency analysis to find the best method for the midwestern United States.
(*f*) Completed.
(*g*) Log-Pearson method was found to be the best for the Midwest. A probability paper for this method is available for quick graphical analysis.
(*h*) Preliminary report available.

061-07357-200-00

NUMERICAL METHOD OF COMPUTING FLOW PROFILES

(*d*) Applied research.
(*e*) Computation of gradually varied steady flow profiles in channels and natural rivers using a numerical method.
(*g*) A computer program is available.
(*h*) **Numerical Method of Computing Flow Profiles,** R. Prasad, *J. Hyd. Div., ASCE* **96,** HY1, pp. 75-86, Jan. 1970.

061-07630-810-00

NONLINEAR HYDROLOGIC SYSTEM RESPONSE MODEL

(*d*) Applied research.
(*e*) A study of nonlinearities in the response of the basin.
(*g*) Nonlinearities in the system response were successfully correlated with the basin main channel and rainfall characteristics.
(*h*) **Nonlinear Hydrologic System Response Model,** R. Prasad, *J. Hyd. Div., ASCE* **93,** HY4, pp. 201-221, July 1967.

061-08138-310-00

A NUMERICAL OPTIMIZATION TECHNIQUE FOR MINIMUM FLOODWAY DELINEATION

(*d*) Applied research.
(*e*) The hydraulic minimum channel cross-section area needed to pass a design flood without appreciable heading is determined automatically from the given total floodplain area.
(*g*) The method has the flexibility whereby the engineer can use his judgement and also be able to delineate the optimal floodway automatically using a computer program. This saves considerable time and effort.
(*h*) Preliminary report and computer program available for a nominal fee.

061-08139-300-00

WATER SURFACE PROFILES IN NATURAL RIVERS

(*d*) Applied research.
(*e*) In conventional methods, computational difficulties are encountered if a natural river is assumed piece-wise prismatic particularly where the changes in the river cross-section are more abrupt. To overcome such difficulties, the natural river is not assumed to be piece-wise prismatic. The intermediate channel cross-sections are linearly interpolated between two surveyed sections during the computation.
(*g*) The advantages of the new technique become quite apparent in case of complex and difficult problems where conventional methods fail to work.
(*h*) Computer program available for a nominal fee.

061-08140-810-00

NONLINEAR RESPONSE OF SMALL INDIANA WATERSHEDS

(*d*) Basic research; experimental.

(*e*) A second-order nonlinear methematical model is used to study the watershed response to the rainfall-excess.
(*h*) Some related reports available.

INGERSOLL-RAND RESEARCH, INC., Fluid Mechanics and Thermal Sciences Department, P.O. Box 301, Princeton, N.J. 08540. Dr. W. A. McGahan, Director of Research.

062-07363-540-00

STUDY OF JET-FLAP CASCADES

(*c*) E. Krasnoff and T. J. Landsberg.
(*d*) Experimental and theoretical; applied research.
(*e*) Study of the performance of jet-flap cascades in rectilinear configuration. Both conventional jet-flap airfoils (normal blowing) and airfoils with jets blowing over rounded trailing edges were evaluated.
(*f*) Completed.
(*g*) Test results on normal blowing jet-flap cascades are in good agreement with a lattice effect theory. Stream turning angle is specified as a function of jet momentum coefficient and cascade solidity. The tangential blowing airfoil configuration typically led to a doubling of cascade performance.
(*h*) **Stream Deflection Produced by a Cascade of Jet-Flap Airfoils,** E. Krasnoff, *J. Basic Engrg., Trans. ASME* **91,** D, 3, 553-5.
An Experimental Study of Rectilinear Jet-Flap Cascades, T. J. Landsberg, E. Krasnoff, *J. Basic Engrg., Trans. ASME* **94,** D, 1, 97-104, Mar. 1972.

062-08600-610-00

OPTIMIZATION OF VALVELESS, PNEUMATIC ACTUATORS

(*c*) E. Krasnoff.
(*d*) Theoretical and experimental; applied research and development.
(*e*) A digital computer model of valveless pneumatic impact tool actuators was developed for the purpose of design optimization. The model accounts for system non-linearities and permits a performance study of the effects of all controllable design parameters. In addition, it permits the evaluation of transient operation (e.g., start-up) and the effects of load characteristics.
(*f*) Completed.
(*g*) A valveless, pneumatic rock drill actuator was optimized under constraints on impact velocity, impact energy and power output. Computer results were in excellent agreement with model test results which included air consumption, impact velocity and frequency, cylinder pressure histories, and piston displacement histories.
(*h*) Internal reports. To be submitted for publication.

062-08601-630-00

REDUCTION OF GAS ENGINE COMPRESSOR PASSAGE PULSATIONS

(*c*) E. Krasnoff.
(*d*) Theoretical; applied research and design.
(*e*) A digital computer model was developed to minimize passage pulsations in reciprocating compressor systems. The model takes into account nonlinear passage and valve flow process as well as the interaction between passages and the compressor cylinders.
(*f*) Completed.
(*g*) Digital computer studies of double acting reciprocating compressor systems have demonstrated the feasibility of significantly reducing compressor passage pressure and riser-pipe flow pulsations. This can be accomplished by proper riser pipe and passage design and it results in important reductions of supercharging effects and pipeline pulsations. The digital computer studies were verified on a compressor-pipeline analog simulator. Analog studies included simulation of six cylinder operation with common inlet and discharge receivers.
(*h*) Internal reports.

062-08603-630-00

THREE-DIMENIONAL DIFFUSERS FOR CENTRIFUGAL COMPRESSORS

(*c*) G. W. Pfannebecker.
(*d*) Experimental and analytical; applied research.
(*e*) Investigation of three-dimensional channel diffusers for centrifugal compressors for the purpose of achieving rapid diffusion rates.
(*f*) Completed.
(*g*) Experimental performance of several diffuser designs was correlated with diffuser design parameters. Efficient three-dimensional diffusion was obtained for properly shaped diffuser vanes, but surge margin was adversely affected by a diverging diffuser sidewall. An analytical method of estimating diffuser performance was formulated which exhibited good agreement with experimental results.
(*h*) Internal report only. To be submitted for publication.

INTERNATIONAL BUSINESS MACHINES CORPORATION, Research Laboratory, Large Scale Scientific Computation Department, Hydrodynamics Group, Monterey and Cottle Roads, San Jose, Calif. 95114. Andrew H. Eschenfelder, Director.

063-07366-740-00

DESIGN, DEVELOPMENT AND APPLICATION OF NUMERICAL METHODS IN THE SOLUTION OF NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS BY FINITE DIFFERENCE METHODS

(*c*) J. E. Fromm, KO7/024.
(*d*) Theoretical; basic research.
(*e*) Finite difference algorithms are designed to replace a set of coupled nonlinear partial differential equations, thereby permitting step by step integration through systems of algebraic equations. Initial-boundary value problems are addressed through conditions established on a finite net of points. The objective is to establish accurate and stable difference approximations, program them for efficient computation, and to test their validity in applications where no other means of solution exist.
(*g*) Fourth order nonlinear algorithms have been developed which extend the range of parameters that may be treated in applications; numerical solutions of buoyant air circulation in rooms.
(*h*) **A Numerical Method for Computing a Non-Linear Time Dependent Buoyant Circulation of Air in Rooms,** J. E. Fromm, *IBM Res. Rept. RJ632*, 1970.
A Numerical Study of Buoyancy Driven Flows in Room Enclosures, J. E. Fromm, *IBM Res. Rept. RJ780*, 1970.

INTERNATIONAL BUSINESS MACHINES CORPORATION, Thomas J. Watson Research Center, Post Office Box 218, Yorktown Heights, N.Y. 10598. Dr. R. E. Gomory, Director.

064-07367-810-20

HYDROLOGY PROGRAM

(*b*) Office of Naval Research.
(*c*) Dr. J. S. Smart.
(*d*) Basic and applied theoretical research.
(*e*) Stochastic hydrology and geomorphology, physical hydrology.
(*h*) **Use of Topologic Information in Processing Data for Channel Networks,** J. S. Smart, *Water Resour. Res.* **6,** 932-936, 1970.

Dependence of Stream Lengths and Drainage Areas on Order: Comment, J. S. Smart, *Water Resour. Res.* **6**, 1424, 1970.

Comment on Use of Runs Test for Measuring Long-Term Persistence, J. R. Wallis, *Water Resour. Bull.* **5**, 818-820, 1970.

Small Sample Properties of H- and K-Estimates of the Hurst Coefficient h, J. R. Wallis, N. C. Matalas, *Water Resour. Res.* **6**, 1583-1594, 1970.

Three-Dimensional, Transient, Saturated-Unsaturated Flow in a Groundwater Basin, R. A. Freeze, *Water Resour. Res.* **7**, 347-366, 1971.

Random-Walk Model of Stream Network Development, J. S. Smart, V. L. Moruzzi, *IBM J. Res. and Dev.* **15**, 197-203, 1971.

In Hydrology h is a Household Word, J. R. Wallis, N. C. Matalas, *Proc. Intl. Symp. on Mathematical Models in Hydrology* **1**, Warsaw, 375-393, 1971.

Correlation Constraints for Generating Procedures, N. C. Matalas, J. R. Wallis, *Proc. Intl. Symp. on Mathematical Models in Hydrology* **II**, Warsaw, 697-705, 1971.

Influence of the Unsaturated Flow Domain on Seepage Through Earth Dams, R. A. Freeze, *Water Resour. Res* **7**, 929-941, 1971.

Computer Simulation of Clinch Mountain Drainage Networks, J. S. Smart, V. L. Moruzzi, *J. Geol.* **79**, 572-584, 1971.

Cis and Trans Links in Natural Channel Networks, J. S. Smart, J. R. Wallis, *Water Resour. Res.* **7**, 1346-1348, 1971.

Correlogram Analysis Revisited, J. R. Wallis, N. C. Matalas, *Water Resour. Res.* **7**, 1448-1459, 1971.

Statistical Properties of Multivariate Fractional Noise Processes, N. C. Matalas, J. R. Wallis, *Water Resour. Res.* **7**, 1460-1468, 1971.

IOWA INSTITUTE OF HYDRAULIC RESEARCH, University of Iowa, Iowa City, Iowa 52240. Dr. John F. Kennedy, Director.

065-00066-810-05

HYDROLOGIC STUDIES, RALSTON CREEK WATERSHED

(*b*) Agricultural Research Service and U.S. Geological Survey.
(*c*) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics, Univ. of Iowa.
(*d*) Field investigation, applied research, and M.S. theses.
(*e*) Study continuously in progress since 1924 on the three square-mile north branch of Ralston Creek. This involves discharge measurement by the U.S.G.S. and rainfall measurement at 5 automatic recording stations. It is collected by the Agricultural Research Service and published by the Weather Bureau. An area of similar size on the south branch of Ralston Creek came under observation in 1967. A record of the urbanization of the area through aerial photos and numerous pictures taken at the same point year after year is being accumulated. Records on rainfall, runoff, groundwater levels, sediment transportation, and land use are combined in an annual report.
(*g*) Yearly records available for examination at Iowa Inst. of Hydraulic Research.
(*h*) Reports prepared annually since 1924 available in files at the Iowa Inst. of Hydraulic Research. Summary of 33-year record published as Bull. 16 of the Iowa Highway Research Board in 1961; available upon request from Iowa Highway Commission, Ames, Iowa.

065-00067-810-30

COOPERATIVE SURFACE-WATER INVESTIGATIONS IN IOWA

(*b*) U.S. Geological Survey, Agric. Research Service, Natl. Weather Service, IIHR, Graduate College.
(*c*) District Chief, Water Resources Div., U.S. Geol. Surv., Iowa City, Iowa.
(*d*) Field investigation; collection of basic streamflow data.
(*e*) Streamflow and sediment measuring stations maintained throughout the State of Iowa cooperatively on a continuous basis. Records collected by standard methods of U.S.G.S.
(*g*) Records of streamflow and sediment discharge computed yearly.
(*h*) Records contained in open-file reports published annually, and in Water-Supply Papers published at 5-year intervals; available from U.S. Geological Survey.

065-00073-700-20

MEASUREMENT OF TURBULENCE IN FLOWING WATER

(*b*) Office of Naval Research, Department of the Navy.
(*c*) Dr. J. R. Glover.
(*d*) Experimental; design.
(*e*) A bi-directional counter to operate with Model Old Gold Hot-Wire Anemometer is being developed. The bi-directional feature will permit direct long-term integrations of products associated with turbulence measurements.
(*f*) Completed.
(*g*) Results obtained from hot wires coated with urethane indicate that coated wires may be used in liquids for a period of approximately one hour before experiencing the usually encountered drift problems. The frequency response of the coated wires has been found to be flat to at least 1 kHz. A vortex shedding technique is used for this evaluation.
(*h*) **A Bi-Directional Counter For Operation with Model Old Gold Hot-Wire Anemometer Systems,** J. R. Glover, *IIHR Report No. 131*, May 1971.

065-01875-000-00

CHARACTERISTICS OF STABLE EDDIES

(*c*) Dr. E. O. Macagno.
(*d*) Experimental and analytical; basic research.
(*e*) Eddies in viscous internal flows are studied both experimentally and theoretically in conduit expansions.
(*g*) Calculations have been completed for eddies in two-dimensional flow expansions which are originated by a sudden jump in the discharge.
(*h*) **Computational Study of Accelerated Flow in a Two-Dimensional Conduit Expansion,** E. O. Macagno, T.-K. Hung, Reprint No. 261.

065-02091-520-20

RESEARCH ON SHIP THEORY

(*b*) Office of Naval Research and Naval Ship Research and Development Center.
(*c*) Dr. L. Landweber.
(*d*) Experimental and theroetical; basic research.
(*e*) Determine the laws governing the forces, moments, and motions of ships. Work is under way on development of procedure for computing potential flow about ship forms; higher-order gravity wave theory for an immersed prolate spheroid; effect of tank size on ship-model resistance; resolution of viscous and wave drag by means of wake and surface-profile measurements; conformal mapping of ship sections; effect of a dilute solution of guar-gum on resistance.
(*h*) **A Longitudinal-Cut Method for Determining Wavemaking Resistance,** D.D. Moran, L. Landweber, *J. Ship Res.* **16**, 1, Mar. 1972.

Natural Frequencies of a Body of Revolution Vibrating Transversely in a Fluid, L. Landweber, *J. Ship Res.* **15**, 2, June 1971.

On the Flow about a Spheroid Near a Plane Wall, C. Farell, *J. Ship Res.* **15**, 3, Sept. 1971.

A Note on Blockage Effect, L. Landweber, *Jubilee Memorial W.P.Z. van Lammeren*, NSMB, 1970.

On the Thick Boundary Layer Near the Tail of a Body of Revolution, K.S.S. Satija, *Ph.D. Thesis*, Univ. of Iowa, Jan. 1971.

Characteristics of Ship Boundary Layers, *8th Symp. Naval Hydrodynamics*, Pasadena, Aug. 1970.

A Nonlinear Numerical-Hydrodynamic Model of a Mechanical Water Wave Generator, *Ph.D. Thesis*, Univ. of Iowa, Aug. 1970.

Higher-Order Theory of Ship Waves from Centerplane Source Distributions, *Ph.D. Thesis*, Univ. of Iowa, Jan. 1972.

The Resistance to Rotation of Free and Enclosed Disk, T. Miloh, M. Poreh, *J. Appl. Mech.* **38,** Ser. E, 4, Dec. 1971.

Rotation of a Disk in Dilute Polymer Solutions, M. Poreh, T. Miloh, *J. Hydronautics* **5,** 2, Apr. 1971, pp. 61-65.

065-03739-730-54

EDUCATIONAL FILMS ON THE MECHANICS OF FLUIDS

(*b*) National Science Foundation.
(*c*) Dr. H. Rouse.
(*h*) Films of series, **Introduction to the Study of Fluid Motion, Fundamental Principles of Flow, Flow in a Gravitational Field, Characteristics of Laminar and Turbulent Flow, Form Drag and Lift, and Propulsion, Effects of Fluid Compressibility,** are now available from Audiovisual Center, Univ. of Iowa.

065-04145-060-00

INTERFACIAL EFFECTS IN FLUID FLOW WITH DENSITY STRATIFICATION

(*c*) Dr. E. O. Macagno.
(*d*) Theoretical and experimental; basic research and graduate theses.
(*e*) Configurations of interface between two layers of fluids of different densities and viscosities.
(*g*) Study of the internal hydraulic jump with mixing has been undertaken both analytically and experimentally.
(*h*) **Internal Hydraulic Jumps with Mixing,** S. Rajagopal, *M.S. Thesis*, May 1971.

065-05908-060-54

EFFECTS OF TURBULENCE AND CURVILINEARITY ON STRATIFIED FLOW

(*b*) National Science Foundation.
(*c*) Dr. E. O. Macagno.
(*d*) Experimental and theoretical; basic research and graduate theses.
(*e*) The effects of curvilinear patterns and turbulent eddies which tend to change existing stratifications are being investigated.
(*g*) Conductivity probes and hot-wire anemometers have been used to study patterns of stratification and flow in a bend. Computational models are under development for circulations due to moving boundaries.
(*h*) **Two-Layer Density Stratified Flow in an Open-Channel Bend,** E. O. Macagno, C. V. Alonso, *Intl. Assoc. Hydraulic Res. Reprint No. 283.*

065-06351-350-10

FLOW-INDUCED EXCITATION OF LOW CREST SPILLWAY

(*b*) U.S. Army Corps of Engineers.
(*c*) Dr. F. A. Locher.
(*d*) Experimental; applied research.
(*e*) Characteristics of the pressure fluctuations on the spillway face are being measured in order to determine whether these fluctuations may excite vibration of a low-crest spillway on an elastic foundation. The investigation focuses on fluctuations on the spillway crest and at the spillway toe for heads between one and four times the spillway height. Effects of a hydraulic jump are considered briefly.
(*f*) Completed.
(*h*) **Some Characteristics of Pressure Fluctuations on Low-Ogee Crest Spillways Relevant to Flow-Induced Structural Vibrations,** F.A. Locher, *IIHR Rept. No. 130*, Feb. 1971.

065-06354-220-61

SEDIMENT TRANSPORT AND RESISTANCE TO FLOW IN ALLUVIAL-CHANNEL BENDS

(*b*) Iowa State Water Resources Research Institute.
(*d*) Experimental; basic research.
(*e*) Investigation of the effects of channel curvature on the energy dissipation and sediment transport characteristics of alluvial channel flows.
(*g*) Experiments are being made in a straight laboratory flume and in a meandering laboratory flume, both partially filled with the same sand. The same mean flow depth and velocity are established in each flume and the energy gradients and sediment transport rates are measured. Meandering channels of two different widths are being utilized. It has been found that meandering has a relatively small effect on the interchange dissipation rate, but a significant effect on the sediment transport rate. For the same flow conditions, transport rate per unit width in the wide meandering channel is roughly 25 percent greater than that in the straight channel, while in the narrower meandering channel it is roughly 50 percent smaller than in the straight channel. The evolution of sand wave spectra from an initially flattened bed is also being investigated in the straight flume. It has been found that at small times the spectra exhibit two dominant frequencies; with the passage of time the variance shifts to the lower frequencies; the spectra become monotonic; for equilibrium bed configurations over a wide range of wave numbers the spectra follow a minus-3 power law. A theoretical model has been developed to explain the observed characteristics of evolving spectra and the occurrence of the equilibrium range.
(*h*) **The Evolution of Sand Wave Spectra,** S. C. Jain, *Ph.D. Thesis*, Jan. 1971.
The Evolution of Sand Wave Spectra, J.F. Kennedy, S.C. Jain, *Intl. Symp. Stochastic Hydraulics*, Univ. of Pittsburgh, June 1971.

065-06356-740-00

NONLINEAR ORDINARY DIFFERENTIAL EQUATIONS IN TRANSPORT PROCESSES

(*c*) Prof. W.F. Ames, Dept. of Mechanics and Hydraulics.
(*d*) Theoretical; basic research.
(*e*) Mathematical investigation of equations resulting from similarity analyses of fluid flow, diffusion, heat conduction and other transport processes.
(*g*) First integrals of some basic equations have been developed using continuous transformation groups.

065-06357-740-00

DEVELOPMENT OF SIMILARITY VARIABLES

(*c*) Prof. W.F. Ames.
(*d*) Theoretical; basic research and graduate theses.
(*e*) Development of continuous transformation groups and their invariants (which are the similarity variables) for a variety of fluid problems.
(*g*) The natural similarity variables for source diffusion problems and heat transfer in non-Newtonian (power law) flow have been developed.
(*h*) **Recent Developments in the Nonlinear Equations of Transport Processes,** W.F. Ames, *Ind. and Eng. Chem. Fund.* **8,** 522, 1969.
Similarity Solutions For Partial Differential Equations Generated by Finite and Infinitesimal Groups, *IIHR Rept. 132*, 1971.

065-06358-740-00

AD HOC METHODS FOR NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS

(*b*) National Science Foundation.
(*c*) Prof. W.F. Ames.
(*d*) Theoretical; basic research and graduate thesis.

(*e*) Development and utilization of a variety of methods including splitting, functional analysis, general solutions and breakdown theories for waves.
(*g*) Large classes of nonlinear hyperbolic equations are obtainable by differentiation of first order equations. The general solutions of these are used to calculate the minimum time for the evolution of solution breakdown (such as shallow water waves breakdown). Applications are shown in shallow water waves, gas dynamics and sound waves.
(*h*) **Discontinuity Formation in Solutions of Homogeneous Nonlinear Hyperbolic Equations Possessing Smooth Initial Data,** W.F. Ames, *Intl. J. Nonlinear Mechanics* 5, 605, 1970.
On Wave Propagation in One-Dimensional Rubberlike Materials, *J. Math. Analysis Appl.* **34,** 214, 1971.
Implicit Ad hoc Methods for Nonlinear Partial Differential Equations, *J. Math. Anal. Appl.*, 1972.
Ad Hoc Methods for Nonlinear Partial Differential Equations, *Applied Mechanics Reviews.*

065-06361-120-00

COMPUTATIONAL MODELING OF NON-NEWTONIAN FLOWS

(*c*) Dr. E.O. Macagno.
(*d*) Analytical; basic research and graduate theses.
(*e*) Unsteady, uniform, and nonuniform non-Newtonian flows are being studied by means of computational models based on discretizations of the corresponding differential equations.
(*g*) Effects of unsteadiness and of finite disturbances have been analyzed using difference schemes. The effect of nonlinear relations in the constitutive equations has been studied in a shear-thickening fluid.
(*h*) **Elementary Numerical Analysis of Some Laminar Flows,** E. O. Macagno, A. Pujol, M. Macagno, *Bull. Mech. Engrg. Educ.* 9, pp. 289-305, Pergamon Press, 1970. Reprint No. 274.
Numerical Experiments on the Stability of Poiseuille Flows of Non-Newtonian Fluids, A. Pujol, *Ph.D. Thesis*, Aug. 1971.

065-06362-020-20

TURBULENT MIXING OF DENSITY STRATIFIED LIQUIDS

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Dr. C. Farell.
(*d*) Experimental and analytical; basic research and graduate thesis.
(*e*) Measurement of the turbulence characteristics of the flow in the wake of a grid towed through a linearly density-stratified liquid, with the aim of determining the effect of the density stratification on the turbulence fluctuations and turbulent mixing, the degree of stratification recovery at various distances behind the grid, and the correlation between turbulent velocity and salinity fluctuations.
(*g*) Experiments have been completed with a 1-1/2 in. square-mesh biplane grid made of 1/2-in. square bars and towed at 0.5 fps through a saline solution with a linear density stratification of 1 percent per foot. The root-mean-square of the longitudinal velocity fluctuations has been found to decrease first, then increase, and, finally level off with distance downstream from the grid. The same trend, but with much smaller variations, is exhibited by the root-mean-square value of the vertical velocity fluctuations. The transverse horizontal component of the velocity exhibits on the other hand the same behavior as in a homogeneous fluid. The cross-correlation between the vertical velocity component and the density fluctuations is a nearly even function at small distances from the grid (as indicated by the values of the quadrature spectra being much smaller than the values of the corresponding cospectra) and becomes a nearly odd function at large distances from the grid (where the quadrature spectra are dominant).

065-06363-060-20

COLLAPSE OF MIXED REGIONS IN DENSITY-STRATIFIED LIQUIDS

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Prof. W. F. Ames and Dr. J. F. Kennedy.
(*d*) Analytical; basic research.
(*e*) Development of a numerical finite difference scheme to describe the profile and internal velocity and pressure distributions of an initially circular region of constant density as it collapses in a surrounding liquid with arbitrary density stratification.
(*f*) Completed.
(*g*) A numerical solution for the case of linear stratification outside the mixed region and potential flow within it has been obtained. The shape of the initial circular region during collapse is approximately elliptical. The vertical collapse occurs quite rapidly, the height of the mixed region being reduced to half of its initial value in about two characteristic time units (based on the Vaisala frequency) for an external density gradient of 0.0155 ft^{-1}. A method of solution has also been developed for the case of viscous motion within the mixed region, and for the approximately one-dimensional motion that occurs at the later stages of collapse. The numerical method of Chorin for obtaining solutions to the Navier-Stokes equations has been extended to the case of moving boundaries.
(*h*) **Wake Collapse Phenomena in Density-Stratified Liquids,** H. Padmanabhan, W.F. Ames, T.K. Hung, J.F. Kennedy, *J. Engrg. Math.* **4,** 229, 1970.

065-06364-200-30

FREE SURFACE SHEAR FLOW OVER A WAVY BOUNDARY

(*b*) U.S. Geological Survey.
(*d*) Experimental and analytical; basic research.
(*e*) Analytical and experimental investigation of the velocity and pressure distributions, surface configuration, and boundary stress distribution of subcritical and supercritical free surface flows over a rigid bed of sinusoidal form.
(*f*) Completed.
(*g*) Experiments have been completed using two different wavy beds. The predictor developed by Kennedy and Iwasa for the amplitude ratio of and phase shift between the bed and surface waves has been verified. Velocity measurements have revealed that the form of the velocity profiles varies widely along each wave length. Streamwise acclerations are produced by the centrifugal pressure gradients over the depth. Phase shifts have been measured between the variation of the bed shear stress and the bed amplitude. The ranges of occurrence of the various surface configurations have been delineated.
(*h*) **Free Surface Shear Flow Over a Wavy Boundary,** Y. Iwasa, J.F. Kennedy, *J. Hyd. Div., Proc. ASCE*, HY2, Mar. 1968.
A Laboratory Investigation of Free-Surface Wavy-Bed Flow, A. Yuen, J.F. Kennedy, *Iowa Inst. of Hydr. Res. Tech. Rept. No. 121*, Dec. 1971.

065-06365-210-20

THE STRUCTURE OF TURBULENT FLOW IN A WAVY BOUNDARY CIRCULAR PIPE

(*b*) Office of Naval Research, Dept. of the Navy.
(*d*) Experimental and analytical; basic research.
(*e*) An experimental investigation of the turbulence array and the velocity, pressure, and shear stress distributions of turbulent flow in a circular pipe whose diameter varies sinusoidally along its length with the aim of establishing the magnitude of the phase shifts between the flow characteristics and the boundary geometry; see 065-06364-200-30.
(*f*) Completed.
(*g*) Experiments in two different wavy-wall pipes, with a mean pipe diameter of five inches, a wave height of 0.220 inches, and wave lengths of 10 to 20 inches, have been

completed. The form of the velocity profile has been found to vary radically along a wave length, the value of n in the power-law distribution ranging from about 6 to 22. In a central core both the mean and turbulent quantities appear to be little affected by the boundary waviness; the major effects are confined to the neighborhood of the boundary. The shear-stress variation is shifted about 0.1 wave length upstream with respect to the boundary wave, the exact value depending on the boundary geometry. An analytical model based on continuity principles and irrotationality of the flow along the pipe centerline has been developed for predicting the variation of the exponent in the power-law velocity distribution.

(*h*) **Turbulent Flow in Wavy Pipes,** S.T. Hsu, J.F. Kennedy, *J. Fluid Mech.* 47, 3, 1971.

065-06617-220-05

FRICTION FACTORS FOR FLOW IN SAND BED CHANNELS

(*b*) Agriculture Research Service, U.S. Dept. of Agriculture.
(*d*) Theoretical; applied research.
(*e*) Development of an improved predictor for depth-discharge relations for all flow regimes in alluvial channels.
(*f*) Completed.
(*g*) Graphical friction-factor predictors have been developed for the flat bed regime and the ripple and dune regime. The predictor for the flat bed regime is in the format of the classical Moody diagram, with the friction factor being expressed as a function of flow Reynolds number and relative roughness (based on the mean particle diameter). The variation of friction factor with Reynolds number is significantly different for mobile channels than for rigid conduits. The additional friction factor resulting from the drag exerted on ripples and dunes is expressed graphically as a function of relative roughness and Froude number based on the mean particle diameter; these variables are arrived at from an analysis of the mechanics of formation of ripples and dunes. Depth discharge relations for several rivers calculated using the proposed technique are in good agreement with measured data.
(*h*) **Sediment Transportation Mechanics; F. Hydraulic Relations for Alluvial Streams,** J. F. Kennedy, *J. Hyd. Div., Proc. ASCE* 97, HY1, Jan. 1971.

065-07368-410-11

SEDIMENT ENTRAINMENT AND SUSPENSION BY SHOALING WAVES

(*b*) Coastal Engrg. Res. Center, U.S. Army Corps of Engineers.
(*c*) Dr. F. A. Locher and Dr. J. F. Kennedy.
(*d*) Experimental and theoretical; basic research.
(*e*) The Iowa Sediment Concentration Measuring System is being used to measure the long-term average, and periodic and random fluctuating components of suspended sediment concentration in shoaling waves in a laboratory wave tank.
(*g*) Experiments have been conducted in a laboratory wave tank in which regular waves break on a beach composed of relatively uniform sand. Experiments have also been conducted to measure the concentration distribution of sand suspended by waves passing over solidified ripples. Instantaneous sediment concentration is measured by the electro-optical system and fed on-line into a high speed computer. A computer program has been developed which allows determination of long-term average concentration; a periodic component of the concentration fluctuations; the RMS of the deviation of the concentration from the periodic value, as a function of phase position within the wave. It has been found that near the bed the velocities induced by the ripples play the dominant role in entraining the sediment and holding it in suspension. A variety of hypotheses concerning the vertical distribution of the effective turbulent exchange coefficient for sediment lead to the results which are in fair agreement with the measured vertical distribution; this demonstrates the relative insensitivity of the predicted concentration distributions to the assumed form of the mixing coefficient.
(*h*) **Sediment Suspension in Shoaling Waves,** P.K. Bhattacharya, *Ph.D. Thesis*, Jan. 1971.
Sediment Suspension by Water Waves, J.F. Kennedy, F.A. Locher, *Advanced Seminar on Waves and Beaches*, Univ. of Wis., Oct. 1971.
Sediment Suspension in Shoaling Waves, *XIV Congress, Intl. Assoc. Hydraul. Res.*, Paris, Sept. 1971.
A Computer Based Electro-Optical System for Measuring Wave Induced Sand Concentration, J.R. Glover, F.A. Locher, *ASME Paper No. 72-FE-8*, Mar. 1972.

065-07369-300-13

RIVER FLOW UNDER ICE

(*b*) Rock Island District, U.S. Army Corps of Engineers.
(*c*) Dr. J. F. Kennedy and Dr. W. W. Sayre.
(*d*) Experimental and field investigation; basic and applied.
(*e*) Measurement of the velocity and temperature distributions, ice thickness, and related meteorological variables for a study site on the Cedar River near Conesville, Iowa. Measurements made before the onset of winter ice, while river is ice covered, and during period of break up during Winter of 1969-70. Conduct of laboratory experiments to investigate the effects of year round navigation on the formation of ice jams.
(*f*) Completed.
(*g*) Measurements of velocity and temperature distributions and ice thickness have been made at regular periods during the winter of 1969-70. It has been found that the temperature is nearly constant over the depth at any section, but varies laterally across the river width. No super-cooling has been observed. The underside of the ice remains smooth while the ice is thickening, but dune-like features occur and the underside becomes rough as the ice melts from below. In the laboratory investigation, simulated ice is used in a laboratory flume to investigate qualitatively the behaviorial aspects of the formation and growth of ice jams.
(*h*) **Two Investigations of River Ice,** G.D. Ashton, M.S. Uzuner, J.F. Kennedy, *Iowa Inst. Hyd. Res. Tech. Rept. 129*, Oct. 1970.

065-07370-300-54

DYNAMICS OF ICE COVERED STREAMS

(*b*) National Science Foundation.
(*d*) Experimental; basic research.
(*e*) An experimental investigation of the kinematics, dynamics, and thermodynamics of the formation and accumulation of river ice, the mechanics of ice-cover breakup and/or melting, the characteristics of flow under an ice cover, and of techniques for ice suppression. The investigation is being conducted in a specially designed tilting flume with refrigerated boundaries and inlet section, located in a temperature controlled room. Efforts to date have been concentrated in four areas; mechanics of ice ripples; ice forces on structures; rate of ice production on free surface flows; ice suppression by large thermal discharges. All phases of the program are proceeding as coordinated experimental and analytical investigations.
(*g*) An analytical model for the stability of the interface between a turbulent flow and ice boundary has been developed and verified with laboratory and field data. Laboratory experiments have been made to determine the effects of flow parameters and air temperature on the rate of surface-ice formation. A numerical model for the suppression of river ice by large thermal discharges has been developed, and experiments to be conducted in the temperature flow facility have been designed to verify the calculation. A technique has been developed for generation of low-strength ice covers composed of small crystals of salt-water ice.
(*h*) **The Iowa Low Temperature Flow Facility,** J.F. Kennedy, *Paper 1.2, Proc. IAHR Symp. on Ice and Its Action on Hydraulic Structures*, Reykjavik, Iceland, Sept. 1970.

One-Dimensional Analysis of Suppression of River Ice by Heated Discharges, C.V. Alonso, submitted to Commonwealth Edison Co., Aug. 1971.
The Formation of Ice Ripples on the Underside of River Ice Covers, G.D. Ashton.
The Formation of Ice Ripples, J.F. Kennedy, G.D. Ashton, *J. Hydraul. Div., ASCE.*

065-07371-340-70

MECHANICS OF COOLING TOWER PLUMES

(*b*) The Marley Company.
(*c*) Dr. S.C. Jain and Dr. J.F. Kennedy.
(*d*) Experimental and analytical; applied and basic research.
(*e*) The trajectory, spread, and dilution of buoyant plumes ejected from mechanical cooling towers have been investigated over a range of cross-wind velocities for both negative and positive buoyancy. Investigations are being conducted in a large resurfaced flume, using heated air or chilled water for stack effluent. The recirculation characteristics of individual towers and interference among different towers are being determined. Towers of various unconventional shapes are being tested in order to determine configurations and layouts which minimize recirculation and interference.
(*g*) Downwind plume configurations, recirculation ratios, and interference ratios have been measured for a variety of tower operating conditions, wind velocities, and tower shapes and arrays. It has been found that the recirculation is more strongly affected by the velocity of cross-winds than by the buoyancy. For each value of the densimetric Froude number there is a value of cross flow which produces a maximum recirculation ratio. A new simularity hypothesis for the velocity distribution of turbulent jets and wakes has been developed.
(*h*) **Model Study of the Recirculation Characteristics of Circular Cooling Towers,** K.S. Hsu, N.S. Huang, J.F. Kennedy, Nov. 1970.
Addendum No. 1, **Recirculation Characteristics for Negative Buoyancy Plumes,** IIHR Limited Distribution Rept., Mar. 1971.
Three Theoretical Investigations of Turbulent Jets, J.-T. Lin, *IIHR Rept. No. 127*, Jan. 1971.
A Laboratory Investigation of Downwind Temperature Distributions and Recirculation of Buoyant Jets Generated by Mechanical Draft Cooling Towers, T.L. Chan, S.T. Hsu, J.T. Lin, K.S. Hsu, N.S. Huang, J.F. Kennedy, IIHR Limited Distribution Rept., Mar. 1971.

065-07372-220-00

THE RELAXATION DISTANCE OF TRANSPORTED SEDIMENT

(*d*) Theoretical and experimental; basic research.
(*e*) Conduct of experiments on the transport of sand through a closed, rectangular cross-section conduit, the top of which is sinusoidal in profile. The profile of the sediment-bed wave produced by the wavy top is being measured for a range of sediment sizes, water temperatures, and flow conditions.
(*f*) Completed.
(*g*) A potential flow formulation was used to predict the velocity field induced by the waviness of the upper and lower boundaries. Velocities obtained from the analysis were incorporated into the transport relation introduced by Kennedy in the modified form of Hayashi's relation to obtain relations between the sediment-transport phase shift, the geometry of the wavy surface, and the depth. Four different sands, with diameters of 0.134 mm, 0.137 mm, 0.235 mm, 0.384 mm, were used in the experiments which were conducted over a temperature range of 9°C to 50°C. Bed profile was measured for a range of flow conditions. The results showed that Kennedy's formulation predicts only the bed-wave amplitude, while a modified form of Hayashi's relation predicts the correct form of the local sediment transport rate to explain the observed behavior of the bed profile. The existence of the phase shift was verified by the fact that there was a corresponding shift between the upper and lower wavy surfaces. The effect of the local bed slope, which is included in Hayashi's formulation, was found to be important in explaining the observed behavior of the bed profile. Velocity profiles and sediment concentration distribution were measured and analyzed. A wide variation of velocity distribution was found along each wave, showing the effects of the longitudinal pressure gradients. Velocity, depth, and concentration were asymmetrically distributed about the bed crescent-cross.
(*h*) **The Local Sediment Transport Rate in Periodically Non-Uniform Flows,** Y.A.N. Akyeampong, *Ph.D. Thesis*, Jan. 1971.

065-07374-270-00

HYDRODYNAMICS OF FLOW IN THE LOWER URINARY TRACT

(*b*) Public Health Service.
(*c*) Dr. C. Farell.
(*d*) Experimental and analytical; basic research and graduate thesis.
(*e*) Analytical and experimental investigation of the flow in the bladder-uretha system, with the aim of developing a theoretical flow model to be used in the analysis and interpretation of micturition data for clinical diagnosis of urinary tract problems.

065-07375-020-36

DISPERSION OF WATER POLLUTANTS IN CURVILINEAR FLOW

(*b*) Environmental Protection Agency.
(*c*) Dr. E.O. Macagno and Dr. W.W. Sayre.
(*d*) Experimental and analytical; basic and applied research; graduate thesis.
(*e*) Study of the separate and joint effects of channel curvature and pollutant buoyancy (positive and negative) on dispersion in open channel flows, with the goal of developing predictors for use in engineering practice.
(*g*) A meandering tilting flume was constructed, and systematic experiments on dispersion of neutrally buoyant simulated contaminants were conducted.
(*h*) **Longitudinal Dispersion in Sinuous Channels,** S. Fukuoka, *Ph.D. Dissertation*, Univ. of Iowa, Jan. 1971.
Lateral Mixing in Meandering Channels, Y.-C. Chang, *Ph.D. Dissertation*, Univ. of Iowa, May 1971.

065-07376-270-40

FLUID MECHANICS OF THE SMALL INTESTINE

(*b*) National Institutes of Health.
(*c*) Dr. E.O. Macagno.
(*d*) Experimental and analytical; basic research, graduate thesis.
(*e*) Study of the flow induced by the motion of the walls of the small intestine by means of physical and mathematical models. Analysis of records taken in human subjects serves to establish the boundary conditions.
(*g*) Statistical study of contractions at a point has been completed. Spatial correlations of contractions are under study. Hydraulic and analytical models of flow induced by wall motion are under operation.
(*h*) **Statistics of Contractions at a Point in the Human Duodenum,** J. Christensen, J. R. Glover, E. O. Macagno, R. B. Singerman, N. W. Weisbrodt, *Amer. J. Physiology* **221**, 6, Dec. 1971, Reprint No. 290.
Computer Recognition of Contractions in the Small Intestine, R.B.J. Singerman, J. R. Glover, *IIHR Rept. No. 134*, Sept. 1971.

065-07377-060-54

MIXING AND TRANSFER PROCESSES FOR HEATED EFFLUENTS IN OPEN CHANNEL FLOW

(*b*) National Science Foundation.
(*c*) Dr. W. W. Sayre.

(*d*) Experimental and analytical; laboratory investigation, applied research.
(*e*) Investigation of the processes by which effluent heated water mixes with flowing streamwater, and the excess heat is transferred to surrounding phases of the environment, and finally, how these processes combine to produce a particular temperature distribution pattern in the stream.
(*f*) Completed.
(*g*) Preliminary analysis of experimental results verify that turbulence tends to dominate the mixing process when the densimetric Froude number is large, but that buoyancy effects leading to vertical stratification and reduced vertical mixing are predominant when the densimetric Froude number is small. Measurements of the longitudinal heat flux have shown that for some conditions significant amounts of heat are transferred to the surrounding environment through the water surface and the channel walls.

065-07378-060-33

NATURAL MIXING AND TRANSFER PROCESSES FOR THERMAL LOADS IN STREAMS

(*b*) Office of Water Resources Research, Dept. of the Interior.
(*c*) Dr. W. W. Sayre.
(*d*) Experimental and analytical; laboratory investigation; applied research, contributing toward Ph.D. and M.S. theses.
(*e*) See 1970 Water Resources Research Catalog.

065-08036-060-33

MIXING AND TRANSFER OF HEAT IN OPEN CHANNEL FLOW

(*b*) Office of Water Resources Research, Dept. of the Interior.
(*c*) Dr. W. W. Sayre.
(*d*) Experimental and analytical, laboratory investigation; applied research, contributing toward M.S. and Ph.D. theses.
(*e*) See 1972 Water Resources Research Catalog.

065-08037-060-33

OPERATIONAL CHARACTERISTICS OF DIFFUSER PIPES FOR DISPERSING HEATED EFFLUENTS IN RIVERS

(*b*) Commonwealth Edison Co., Chicago; Office of Water Resources Research, Dept. of the Interior.
(*c*) Dr. W. W. Sayre.
(*d*) Experimental, laboratory investigation; applied research for M. S. theses.
(*e*) Investigation of the operating characteristics of buried multiple-port diffuser pipes for dispersing heated effluents in rivers with a view toward evaluating the degree of mixing in the channel downstream as a function of the spacing of discharge ports, and eliminating and/or suppressing thermal wedges which occur upstream from diffuser pipes at low densimetric Froude numbers.
(*g*) In the mixing investigation the spacing between ports was varied from 0.6 to 2.5 times the flow depth for a fairly wide range of simulated low river flow conditions. Rapid mixing was observed for all configurations provided that a critical momentum flux ratio (ratio of width-averaged ambient momentum flux to width-averaged effluent momentum flux) did not exceed a critical value which depends on the source Froude number (ratio of ambient velocity cubed to width-averaged buoyancy flux) in which case stratification tends to occur. In the thermal wedge investigation of the effectiveness of various types, configuration and combinations of structures such as sills, wind walls, and floating barriers for eliminating and/or suppressing the wedge were studied. The most promising arrangements consist of floating barriers located a short distance upstream from the diffuser pipe, and a combination of a sill and width contraction a short distance downstream from the diffuser pipe.

065-08038-050-20

TURBULENT JETS IN CROSS-FLOWS

(*b*) Office of Naval Research, Dept. of the Navy.
(*d*) Experimental and theoretical; basic research.
(*e*) Experiments are being conducted in an open-throat wind tunnel using a control-box on the sides of the jet. Distributions of velocity and pressure are measured at the upstream and downstream ends of the box, in order to determine the entrainment of fluid and momentum by the jet up to any elevation. The analytical model is directed toward determining the entrainment of the function of jet trajectory.
(*g*) Detail pressure measurements around the jet in the plane of the orifice have revealed larger pressure variations than for the case of flow around a rigid body. Equations have been developed which predict the dilution along the jet in terms of its measured trajectory, for the case of non-buoyant jets. The model is presently being extended to the case of buoyant jets.

065-08039-042-15

NONLINEAR WAVE PROPAGATION

(*b*) U.S. Army.
(*c*) Prof. W. F. Ames, Dept. of Mechanics and Hydraulics.
(*d*) Theoretical; basic research, graduate thesis.
(*e*) Analytic investigation of influence of nonlinear free surface condition on waves by general solution techniques.

065-08040-220-05

TURBULENT STRUCTURE OF SEDIMENT SUSPENSIONS

(*b*) Agricultural Research Service, U.S. Dept. of Agric., Oxford, Miss.
(*c*) Dr. C. Farell.
(*d*) Experimental and analytical; basic research and graduate thesis.
(*e*) Measurement of the turbulent velocity fluctuations in a sediment-laden flow and simultaneous measurement of the sediment-concentration fluctuations as a step towards the understanding of the mechanism by which sediment particles are entrained from the bed and carried into suspension, and for the eventual formulation of analytical models for the entrainment process.

065-08041-000-00

INSTABILITY OF VORTEX MOTION

(*c*) Dr. C. J. Chen.
(*d*) Experimental and theoretical; basic research.
(*e*) The instability of vortex motion is observed from a moving vortex ring. Extended Karman-Pohlhausen integral method is used to predict critical Reynolds number, wave length, and critical time.
(*g*) Experimental data on laminar-turbulent patterns are obtained.
(*h*) **Flow Patterns of a Circular Vortex Ring with Density Difference Under Gravity,** *J. Appl. Mech.*, 1972 (or *ASME Paper No. 72-APM-1*).
Hot-Wire Measurement of the Velocity Distribution in a Circular Vortex Ring, C. E. Lee, *M. S. Thesis*, Dept. of Mech. Engrg., Univ. of Iowa, June 1971.

065-08042-010-21

THICK BOUNDARY LAYERS NEAR THE TAIL OF BODIES OF REVOLUTION

(*b*) Naval Ship Research and Development Center.
(*c*) Dr. V. C. Patel.
(*d*) Experimental and theoretical; basic research.
(*e*) The purpose of the project is to study the behavior of an axisymmetric turbulent boundary layer that is thick in comparison with the local radius of the body, and the potential flow outisde it. Experiments are being performed on a 5 ft. long spheroidal model to measure the mean-velocity profiles, static-pressure distributions, and turbulent velocity fluctuations and Reynolds stresses across the thick boundary layer near the tail of the body. Methods are being developed for the calculation of thick axisymmetric boundary layers and the interaction. The latter will lead to the pressure field near the tail and hence to a better prediction of the drag of the body.

(*g*) The experimental phase of the project is nearing completion. It has been found that conventional boundary layer calculation methods do not adequately predict the development of a thick boundary layer. Using the present experimental results, attempts are being made to extend some of the well-known methods to treat thick boundary layers.
(*h*) **On the Thick Boundary Layer Near the Tail of a Body of Revolution,** K. S. S. Satija, *Ph.D. Thesis*, Univ. of Iowa, Jan. 1971.

065-08043-300-13

MECHANICS OF RIVER ICE JAMS

(*b*) Rock Island District, U.S. Army Corps of Engineers.
(*d*) Theoretical and experimental; basic and applied research.
(*e*) A coordinated theoretical and laboratory investigation of the mechanics of formation and evolution of ice jams in rivers. Three aspects of the problem have been selected for investigation; the stability against submergence of floes at the upstream end of floating ice cover; the stress distribution in ice jams composed of fragmented ice; the transport of floes under a floating cover. The experiments are being made in the laboratory flume and make use of simulated floes, made from wood and paraffin, of idealized shape.
(*g*) Analytical model based on one-dimensional hydraulics and the moment stability of a buoyant block of right parallelepiped form has been developed to predict the conditions for incipient submergence by rotation of blocks at the leading edge of ice cover. The critical conditions for submergence are predicted in terms of the Froude number of the approach flow, and the ratios of thickness to flow depth and block thickness to length. Analysis has been verified with results of laboratory experiments made using large blocks with different specific gravities. Results of the investigation led to a conjecture concerning the evolution to equilibrium of ice jams in natural streams. The equations governing the stress distribution in an ice jam have been derived, and tests are currently under way to determine the constituatory relations the analysis embodies.
(*h*) **Stability of Floating Ice Blocks,** M. S. Uzuner, *M. S. Thesis*, Univ. of Iowa, May 1971.
The Stability of Floating Ice Blocks, J. F. Kennedy, M. S. Uzuner, *J. Hyd. Div., Proc. ASCE* **98,** HY12, Dec. 1972.

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IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY, Department of Agricultural Engineering, Ames, Iowa 50010. Dr. H. P. Johnson, Professor.

066-0017W-810-00

PHYSICAL AND ECONOMIC ANALYSIS OF WATERSHEDS

See Water Resources Research Catalog **6,** 6.0352.

066-0106W-830-00

RELATIONSHIP OF HYDROLOGY AND SOILS TO GULLY DEVELOPMENT

See Water Resources Research Catalog **6,** 2.0693.

066-0107W-870-00

STUDY OF SEDIMENT POLLUTION AND MOVEMENT BY ACTIVATION ANALYSIS PRINCIPLE

See Water Resources Research Catalog **6,** 5.0512.
(*c*) Dr. C. E. Beer.

066-0155W-810-00

HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS

See Water Resources Research Catalog **6,** 2.0692.

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IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY, Department of Agronomy, Ames, Iowa 50010. Dr. Don Kirkham.

067-0156W-820-00

MOVEMENT OF WATER AND GASES IN SOIL

See Water Resources Research Catalog **7,** 2.0657.

067-0157W-070-00

GROUNDWATER SEEPAGE PATTERNS TO WELLS FOR UNCONFINED FLOW (PHASE II)

See Water Resources Research Catalog **7,** 8.0330.

067-0158W-820-00

FLOW PATTERNS OF RAINWATER THROUGH SLOPING SOIL SURFACE LAYERS AND THE MOVEMENT OF NUTRIENTS BY RUNOFF

See Water Resources Research Catalog **7,** 4.0192.

067-0159W-040-00

SOLUTION OF SOME POTENTIAL FLOW PROBLEMS FOR REGIONS OF ARBITRARY SHAPE BY A NON-ORTHONORMAL POLYNOMIAL METHOD

See Water Resources Research Catalog.

067-0160W-820-00

SOIL STRUCTURE AND CROP PRODUCTION

See Water Resources Research Catalog.

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IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY, Department of Engineering Mechanics, Ames, Iowa 50010. Professor Donald F. Young.

068-07392-270-40

EFFECT OF STENOTIC OBSTRUCTIONS ON FLOW IN TUBES

(*b*) Iowa State Univ. Engr. Research Inst.; Public Health Service.
(*d*) Experimental and theoretical; basic research.
(*e*) Project is concerned with steady and unsteady flow of liquids through circular tubes which contain some type of constriction. Flow characteristics which may be of importance to blood flow through arteries containing stenoses are being studied. These include pressure distribution, laminar separation phenomena, and transition Reynolds numbers for the initiation of turbulence. Both *in vitro* and *in vivo* tests are under consideration.
(*h*) **Flow Through a Converging-Diverging Tube and Its Implications in Occlusive Vascular Disease,** J. H. Forrester, D. F. Young, *J. Biomechanics* **3,** pp. 297-316, 1970.
Hydrodynamics of Arterial Stenoses–A Review, *Engr. Res. Inst. Tech. Rpt. 77300*, Iowa State Univ., 1970.
Fluid Mechanics of Arterial Stenoses, D. F. Young, F. Y. Tsai, *Proc. 8th Ann. Rocky Mountain Bioengineering Symp.*, pp. 138-142, 1971.
Influence of Geometry on Flow in Models of Arterial Stenoses, D. F. Young, F. Y. Tsai, B. E. Morgan, *Proc. 24th Ann. Conf. on Engr. in Med. and Biology*, p. 325, 1971.
Flow Through a Model of An Arterial Stenosis, B. E. Morgan, *M. S. Thesis*, Iowa State Univ., 1971.

068-08141-270-00

CELLULAR RESPONSE TO FLOW

(*b*) Iowa State Univ. Engr. Research Institute.
(*d*) Experimental; basic research; thesis.

(*e*) Living cells grown as an attached, confluent monolayer are subjected to a steady, uniform laminar flow. The cells are grown in a specially designed cell culture chamber in which the flow conditions over the cells may be precisely defined and are experimentally verified.
(*f*) Completed.
(*g*) The observed responses of the cells in the attached geometry are described for shear stesses ranging from 10^{-3} to 10 dyne/cm^2. The relative importance of the rheological properties of the cellular components is seen to vary with the magnitude of the shear stress applied. The significance of such flow studies to site predilection in atherosclerosis is discussed in following publications.
(*h*) **An *In Vitro* Study of Flow Response by Cells,** J. W. Krueger, D. F. Young, N. R. Cholvin, *J. Biomechanics* **4**, pp. 31-36, 1971.
An *In Vitro* Study of Cellular Response to Flow with Special Reference to the Cardiovascular System, J.W. Krueger, *Ph.D. Thesis*, Iowa State Univ., 1971.

068-08142-270-00

ULTRASONIC DETECTION OF TURBULENCE

(*b*) Iowa State Univ. Engr. Research Institue.
(*d*) Experimental and theoretical; basic research, thesis.
(*e*) Project is concerned with the use of ultrasonic flowmeter to detect turbulence in internal flows. Special application of interest is detection of turbulence in arterial blood flow.

UNIVERSITY OF IOWA, College of Engineering, Department of Mechanical Engineering, Iowa City, Iowa 52240. Professor Robert G. Hering, Department Chairman.

070-06109-140-00

HEAT TRANSPORT IN TURBULENT FLOWS WITH INTERNAL HEAT SOURCES

(*c*) Professor J. M. Trummel.
(*d*) Experimental; basic research.
(*e*) Development of suitable experimental systems permitting measurement of mean temperature distribution; measurements in statistically analogous systems.
(*f*) Completed.
(*g*) Measurements have been made on one flow geometry with chemical internal heat generation and with an analogous system. Measurements also have been made on circular tube flow using the analogy approach.
(*h*) **Mean Temperature Distribution in Reacting Turbulent Flow with Uniform Internal Heat Generation,** J. M. Trummel, *Department Rept.* and *M. S. Thesis*, Univ. of Iowa, Aug. 1965 (available in Library).
Transient Temperature Response of Steady Uniform Flow With a Steadily Rising Inlet Temperature, *M. S. Thesis*, Univ. of Iowa, Aug. 1970.

070-06111-130-00

LIQUID-VAPOR INTERFACIAL WAVES ON VERTICALLY FLOWING FILMS FORMED BY A CONDENSING VAPOR

(*c*) Dr. D. L. Spencer.
(*d*) Experimental; basic research.
(*e*) A study is being made of the stability of the layer for condensation in the presence of non-condensables.
(*g*) For certain combinations of condensable and non-condensable gaseous species, the diffusion layer is unstable at moderate and high condensation rates. Under these conditions, cells appear to develop in the vapor as it drifts toward the condenser so that non-condensables are carried toward and away from the plate in eddy motion generated by the cells. These cells give rise to vertical undulations on the condensation film. As a result of this strong eddy transport of non-condensable gases, heat transfer coefficients are only slightly reduced even for moderate concentration of non-condensable gases.

070-06112-000-00

INTERACTION BETWEEN VORTEX FLOW AND TWO-DIMENSIONAL JET FLOW

(*c*) Professor G. M. Lance.
(*d*) Experimental; Doctoral thesis.
(*e*) A study is being made of the flow characteristics in the finite vortex flow.
(*f*) Completed.
(*h*) **Vortex Induced and Forced Switching of Two-Dimensional Jets,** *ASME Paper 70 WA/Flcs-131970.*
Vortex Switching of Plane Jets, *Ph.D. Dissertation*, Univ. of Iowa, Feb. 1970.

070-07393-130-00

SYMMETRICAL AND UNSYMMETRICAL EXPLOSIONS IN A VAPOR-DROPLET MIXTURE

(*c*) D. C. Chou.
(*d*) Theoretical analysis; basic research.
(*e*) Basic research in the area of aerophysics of air pollution. Wave propagation in chemically reacting gas-particle systems.

UNIVERSITY OF IOWA, IOWA INSTITUTE OF HYDRAULIC RESEARCH, see IOWA INSTITUTE OF HYDRAULIC RESEARCH

JET PROPULSION LABORATORY, see CALIFORNIA INSTITUTE OF TECHNOLOGY

UNIVERSITY OF KANSAS, School of Engineering, Department of Civil Engineering, Lawrence, Kans. 66044. Professor Yun-Sheng Yu.

The following projects conducted by the Water Resources Research Institute (Dr. G. S. Clausen, Director) are reported in Water Resources Research Catalog;

071-0108W-860-00

WATER UTILIZATION ASPECTS OF WEATHER MODIFICATION AS APPLIED TO KANSAS

071-0111W-870-00

BALANCED STORM DRAINAGE

See *WRRC* **6**, 8.0312.

071-0113W-810-00

DETERMINATION OF DISCHARGE-FREQUENCY RELATIONSHIPS FOR SMALL DRAINAGE AREAS

See *WRRC* **6**, 2.0727.

071-0161W-810-00

THE DEVELOPMENT AND FIELD TESTING OF A BASIN HYDROLOGY SIMULATOR

See *WRRC* **7**, 2.0681.

071-07395-330-00

HYDRAULICS OF NAVIGATION CANALS AND LOCKS

(*c*) Dr. J. S. McNown.
(*f*) Suspended.
(*g*) In exploratory experimental studies the effect of canal size on the virtual mass of the system was found to be less than anticipated and difficult to measure accurately, and the wave velocity in channels with various cross sections was found to be predictable from the average depth.

071-07397-300-00

TURBULENT DISPERSION AND ATMOSPHERIC REAERATION IN NATURAL STREAMS

(*e*) To develop a mathematical model for the turbulent dispersion in natural streams; to determine the reaeration coefficient for natural streams based on the analysis of field data available; to find the relationship between the turbulent dispersion and the atmospheric reaeration, if any.
(*f*) Completed.
(*g*) Analysis of available data on dye tests and on reaeration coefficients of different reaches of natural streams was made. The results show that the dimensionless dispersion parameter and the Reynolds number of flow are linearly related on a log-log plot. A similar relation exists between the dimensionless reaeration parameter and the Reynolds number.
(*h*) **Longitudinal Dispersion and Reaeration in Natural Streams,** *Natl. Fall Mtg., AGU*, Paper No. H-45, San Francisco, Calif., Dec. 1970.
Dispersion in Natural Streams, M. K. Bansal, *J. Hydraul. Div., ASCE* 97, HY11, Nov. 1971.

071-07398-290-00

OSCILLATIONS OF LIQUID IN TANDEM TANKS

(*d*) Theoretical and experimental; basic research for Doctoral thesis.
(*e*) The damped-free oscillations of liquid in tandem tanks are determined theoretically and experimentally. The instantaneous water level in the tank is measured and calculated to determine the frequency and damping of oscillations.
(*f*) Completed.
(*g*) The measured water level versus time agrees fairly well with the computed curved based on one-dimensional analysis. The essential features of the damped-free oscillations in tandem tanks are quite similar to those for a U-tube.

071-08048-370-61

HIGHWAY STORM DRAINS

(*b*) Kansas Water Resources Research Institute.
(*c*) Dr. J. S. McNown.
(*d*) Experimental and applied.
(*e*) A model inlet based on practice in the Kansas State Highway Commission was tested in laboratory to determine the distribution of flow in gutter and proportion of flow in gutter captured by the inlet for various slopes and discharges, and the effect of design modifications.
(*f*) Completed.

071-08049-210-00

UNSTEADY FLOW THROUGH A PIPE ORIFICE

(*d*) Theoretical and experimental; basic research for Doctoral thesis.
(*e*) Unsteady laminar flows through a pipe orifice due to a suddenly imposed constant pressure gradient and a time-dependent pressure gradient are investigated, respectively. Experiments on laminar oscillatory flow through a pipe orifice are also being conducted.

071-08050-870-61

LOCALIZED THERMAL POLLUTION IN SHALLOW STREAMS

(*b*) Kansas Water Resources Research Institute.
(*d*) Experimental and theoretical.
(*e*) Laboratory experiments are conducted to determine the effect of thermal discharge into a shallow stream on its temperature distribution. Predictive method will be developed to determine the temperature distribution.

071-08051-870-73

BASELINE STUDY OF LA CYGNE LAKE, KANSAS

(*b*) Kansas City Power and Light Company and Kansas Gas and Electric Company.
(*d*) Experimental.
(*e*) A baseline study of the La Cygne Lake as a cooling lake for power generation is conducted by an interdisciplinary team of staff members and students from the University of Kansas. The objectives are 1) to establish seasonal variation of temperature distribution, water quality, and biota prior to power plant startup; 2) to estimate the seasonal circulation pattern in lake; and 3) to predict the effects of future heated water discharges on 1) and 2).

UNIVERSITY OF KENTUCKY, College of Engineering, Department of Civil Engineering, Lexington, Ky. 40506. Professor Don J. Wood.

072-08052-130-54

EFFECT OF TRANSIENT FLOW CONDITIONS ON SOLID PARTICLES MOVING THROUGH A VISCOUS LIQUID

(*b*) National Science Foundation.
(*c*) T. Y. Kao, Asst. Professor.
(*d*) Analytical and experimental, basic research.
(*e*) Study of the hydrodynamic behavior of a solid spherical particle and particles moving in a viscous fluid under the action of pressure waves.
(*g*) Analysis and experiments on single sphere completed. Two spheres moving along and perpendicular to their center line, in progress.

072-08053-830-00

STUDY OF MECHANICS OF GULLY FORMATION AND DEVELOPMENT AND ITS EFFECT ON SEDIMENT YIELD

(*b*) Office of Water Resources Research.
(*c*) T. Y. Kao, Asst. Professor.
(*d*) Analytical and experimental; applied research.
(*e*) Study of the basic mechanics of gully formation and growth under controlled conditions.

072-08054-040-00

HYDRODYNAMIC DRAINAGE DUE TO IMPACT MOTION

(*c*) T. Y. Kao, Asst. Professor.
(*d*) Analytical and experimental, basic and applied research.
(*e*) Study of the flow characteristics and pressure distributions due to impact of a circular plate lying on the surface of a liquid of finite depth.
(*g*) Potential flow model is used to complete the analytical derivation, experimental study under way.

072-08055-210-00

ANALYTICAL METHODS FOR TRANSIENT PIPE FLOW ANALYSIS

(*c*) Professors D. J. Wood, S. E. Jones.
(*d*) The study is analytical–solutions of the wave equation with various boundary conditions are being obtained.
(*e*) Obtain improved techniques for analyzing transient flow of liquids in pipes.
(*g*) Solutions of the wave equation for a slowly closing valve have been obtained. Viscous effects have been approximated. Some charts for the prediction of pressure surge magnitudes due to valve closures have been obtained.

072-08056-390-33

OPTIMUM DESIGN OF HYDRAULIC NETWORKS

(*b*) Office of Water Resources Research.

(*d*) Analytical study of the economics and hydraulics of hydraulic networks design. Digital and analog–hybrid models are being considered.
(*e*) Develop a model for minimum cost design of hydraulic networks.
(*g*) Several techniques for handling the hydraulics of the networks have been developed. These include an analog model and a linearized model. A digital analysis using geometric programming has been somewhat successful in obtaining a minimum cost design and this analysis is being refined.

072-08057-270-29

FLOW IN THE CARDIOVASCULAR SYSTEM

(*b*) Themis, Department of Defense.
(*d*) Analytical study of cardiovascular model evaluating the effect of lumping parameters. Analytical and experimental study of the flow characteristics of distribution networks with many tubes.
(*e*) Develop improved modeling of the cardiovascular system.
(*g*) It has been shown that lumping of system resistance and compliance has significant effect on the predicted responses. Also, it has been shown that network geometry can be correlated reasonably well to the flow characteristics of the network without considering basic fluid mechanics concepts.

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LAMONT-DOHERTY GEOLOGICAL OBSERVATORY of Columbia University, Palisades, N.Y. 10964. Robert Gerard, Senior Research Associate.

073-08058-450-52

MIXING DIFFUSION AND CIRCULATION RATES IN OCEAN WATERS

(*b*) U.S. Atomic Energy Commission.
(*d*) Theoretical and/or field investigation; basic research.
(*e*) The work reported here includes studies of diffusion and circulation in oceans and lakes. Techniques used for these studies include dye diffusion methods at the surface and subsurface, hydrographic methods, aerial photogrammetry, and radon analysis.
(*g*) Studies of mixing and circulation in the surface mixed layer in natural water bodies have been accomplished using aerial photographic measurements of dye and floating cards and radon profile data. The most intensive vertical circulation observed was associated with large Langmuir cells where the maximum spacing of convergence lines was 280 meters in the Western Atlantic and 130 meters in Lake Ontario. The apparent vertical diffusion associated with the large Langmuir cells is on the order of 1000 cm^2/sec.
(*h*) **Some Mechanisms of Oceanic Mixing Revealed in Aerial Photographs,** G. Assaf, R. Gerard, A. L. Gordon, *J. Geophysical Res.* **76**, 27, pp. 6550-6572, Sept. 20, 1971.
Circulation and Mixing in Lake Ontario, R. Gerard, G. Assaf, *Bull. Amer. Meteorological Soc.* **52**, 9, pp. 921-940, Sept. 1971.

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LEHIGH UNIVERSITY, Department of Civil Engineering, Fritz Engineering Laboratory, Bethlehem, Pa. 18015. Dr. Walter H. Graf, Director, Hydraulic and Sanitary Engineering Division.

074-05822-390-13

GAS REMOVAL SYSTEMS ASSOCIATED WITH DREDGE PUMPS

(*b*) District Engr., U.S. Army Engr. Dist., Marine Div., Philadelphia, Corps of Engineers.
(*d*) Applied research.
(*e*) Study of the effect of gas removal systems on centrifugal dredge pumps. This consists of a program of studies, tests, analysis and reports dealing with ways and means for efficiently removing entrained and dissolved gases from the effluents of dredging with centrifugal pumps in rivers and harbors. The project has been divided into four phases, (a) Literature Search and Formulation of a Test Program, (b) Formulation of Specific Test Setup and Schedule of the Tests with Water, (c) Experimental Study and Analysis of Test Results, and (d) Experimental Study with Solid-Water Mixtures (mud) and Analysis of Test Results.
(*f*) Completed.
(*h*) **Gas Removal Systems; Study of the Top Horizontal Discharge Pump,** O. A. Elghamry, R. P. Gupta, *F.L.R. No. 310.23*, 1971.
Gas Removal System; Model Study–Final Report, J. R. Adams, R. P. Gupta, *F.L.R. No. 310.22*, 1970.

074-06562-220-00

STUDIES ON THE SETTLING VELOCITY

(*d*) Applied research.
(*e*) Model investigation in the determination of the settling velocities of artificial and natural particles.
(*f*) Completed.
(*h*) **Modified Rubey's Law...; A Discussion,** W. H. Graf, *Water Resour. Res.* **6**, 3, 1970.
Observation On An Unusual Parameter for Grain Fall Velocity, Discussion by W. H. Graf, *Proc. Inst. Civil Engrg.* **49**, 1971.

074-06564-260-36

THE TRANSPORT OF SOLID SUSPENSION IN CONDUITS

(*b*) Environmental Protection Agency; Lehigh University, Inst. of Research.
(*d*) Experimental and theoretical; applied research; dissertations.
(*e*) The transport phenomenon of solid-liquid flow in a conveyance system is studied. General relationships between flow parameter and sediment transport are established. The critical deposit velocity is described. A modified Venturi meter was tested.
(*h*) **Critical Velocity for Solid-Liquid Mixtures; The Lehigh Experiments,** W. H. Graf, et al., *F.L.R. No. 353.1*, July 1970.
Measurement of Solid-Liquid Flow; A Modified Venturimeter, W. H. Graf, et al., *Proc., Symp. on Flow*, Pittsburgh, Pa., 1971.
Pipelining of Low-Concentration Sand-Water Mixtures, M. Robinson, W. Graf, *Proc. ASCE* **98,** HY7, 1972.
Sediment Transport in Closed Pipes, in *Hydraulics of Sediment Transport*, W. H. Graf, McGraw-Hill, New York-London, 1971.

074-07402-700-00

FREE OVERFALL

(*d*) Experimental, applied research; Master's thesis.
(*e*) The possibility of using the free overfall as a flow measuring device is investigated.
(*f*) Completed.
(*h*) **The Free Overfall as a Flow Measuring Device,** S. Bauer, W. Graf, *Proc. ASCE* **97,** IR1, 1971.

074-07403-370-60

DEVELOPMENT OF IMPROVED DRAINAGE INLETS

(*b*) Commonwealth of Pennsylvania, Dept. of Highways.
(*d*) Experimental; applied research.
(*e*) Highway drainage inlets currently in use are tested at a model: prototype ratio of 1:2 to determine the capacity of each for the conditions in which it is used. This information will be used to develop more efficient drainage inlets.
(*h*) **Hydraulic Performance of Highway Drainage Inlets Used in Pennsylvania,** P. P. Yee, W. H. Graf, A. W. Brune, *F.L.R. No. 364.3*, 1972.

Study of Highway Drainage Inlets, G. Lee, *M.S. Thesis*, Lehigh Univ. Library, 1970.

074-07404-030-00

EFFECT OF FREE STREAM TURBULENCE ON DRAG COEFFICIENT

(*d*) Applied research; Ph.D. dissertation.
(*e*) The effect of free stream turbulence on the drag coefficient of a two-dimensional circular cylinder is investigated. The experiments were conducted in a Reynolds number range from 800 to 40,000.
(*f*) Suspended.
(*h*) **Tests on Cylinders in Turbulent Flow**, W. H. Graf and S. C. Ko, *Proc. ASCE* **97**, HY8, 1971.
Drag Coefficient and Turbulence Characteristics, *Proc. IAHR, XIV Cong.*, Paris, 1971.

074-08059-220-00

HYDRAULICS OF SEDIMENT TRANSPORT

(*d*) Theoretical, textbook and/or reference book.
(*e*) A book has been written with the following contents. *A Short History Of Sediment Transport:* Some prehistoric and historic documents up to 1500 A.D. Hydraulics as a science, from L. daVinci to P. Forchheimer. *Hydrodynamics Of Fluid-Particle Systems:* General remarks. Settling velocities of particles. Effect of particles on the fluid-viscosity. *Sediment Transport In Open Channels:* Scour criteria and related problems. The bed-load. The suspended load. The total load. The regime concept. Bedform mechanics. Cohesive-material channels. Sediment measuring devices. Model laws. *Sediment Transport In Closed Pipes:* Flow of solid-liquid mixtures in pipes. Measuring devices for solid-liquid mixtures.
(*f*) Completed.
(*h*) **Hydraulics of Sediment Transport**, W. H. Graf, McGraw-Hill Book Co., New York, N.Y.; Maidenhead, G. B., Duesseldorf, Germany; Ediscience SA, Paris, France.

074-08060-420-00

TRANSMISSION AND REFLECTION OF WAVE ENERGY BY A HORIZONTAL OBSTACLE

(*d*) Experimental and analytical; Ph.D. thesis.
(*e*) Interaction of waves with a horizontal plate has shown a confused wave form at the leeward side of the plate. Analytical and experimental attempts will be made to relate the incoming wave power spectrum and the transmitted wave power spectrum.

074-08061-130-00

WALL SHEAR STRESS IN TURBULENT PIPE FLOW OF SOLID-LIQUID MIXTURES

(*d*) Experimental; Ph.D. thesis.
(*e*) Experiments are conducted to determine the effect of sand suspensions on the wall shear stress in turbulent pipe flows. Uniform natural sands of 0.45 mm and 0.88 mm in average size are used. The wall shear stress is measured with a special hot-film sensor mounted flush with the pipe wall. Concentrations of up to 2 percent by volume were obtained with a Reynolds number range of 8×10^4 to 7×10^5 through a 3-in. plexiglass pipe.
(*g*) Results seem to indicate that there is an increasing effect of the sand suspensions with increasing concentration on the wall shear stress. This effect seems to be larger for the larger sized sand.
(*h*) **Turbulence Characteristics of Solid-Mixtures: Phase 1–A Wall Shear Stress**, W. H. Graf, O. Yucel, *AIChE 70th Natl. Mtg.*, Atlantic City, N.J., Paper No. 18c, Aug. 29-Sept. 1, 1971.

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LEHIGH UNIVERSITY, Department of Mechanical Engineering and Mechanics, Bethlehem, Pa. 18015. Professor J. A. Owczarek.

075-08062-600-20

FLUID AMPLIFIERS

(*b*) Office of Naval Research.
(*d*) Experimental and theoretical; basic and applied research for thesis (Master's or Doctoral).
(*h*) Reports available NTIS, Springfield, Va. 22151:
A Study of Flow from Two Planar Nozzles, J. A. Owczarek, D. O. Rockwell, Y. S. Cha, June 1970, AD711313.
The Effect of Nozzle Geometry on the Total Pressure Distribution in Wall Jets on a Circular Attachment Wall and on Jet-Wall Edge Interaction, J. A. Owczarek, D. O. Rockwell, Y. S. Cha, June 1970, AD711314.
Switching Dynamics of Bistable Fluid Amplifiers, M. R. Ozgu, A. H. Stenning, Mar. 1971, AD723832.
Natural Breakdown of Planar Jets, D. O. Rockwell, W. O. Niccolls, June 1971, AD730716.
High Frequency Jet Excitation, D. O. Rockwell, June 1971, AD730717.
Coaxial Impingement of Axisymmetric Jets, D. O. Rockwell, E. M. Herrold, June 1971, AD730718.
An Experimental Study of the Switching Dynamics of Monostable Fluid Amplifiers, M. R. Ozgu, A. H. Stenning, Oct. 1971, AD733077.
Dynamic Modeling of the Bistable Fluid Amplifier, J. P. Ries, Jan. 1972, in press.

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LOCKHEED-CALIFORNIA COMPANY, Ocean Laboratory, 3380 North Harbor Drive, San Diego, Calif. 92101. L. D. Coates, Division Manager.

076-08063-420-00

WIND/WAVE FORECASTING/HINDCASTING

(*c*) Dr. H. Chin.
(*d*) Theoretical; applied research.
(*e*) The vector wind field at a specified height over the ocean will be derived from synoptic data and ship reports according to a statistical scheme based on recent developments in bulk aerodynamic theory. These winds will then be used to predict the deep-water wave field through the use of a modified version of a presently available wave prediction scheme. This program consists basically of three parts: Spectral growth according to a Miles-Phillips mechanism; dissipation according to empirical relations; and propagation by a gradient system. Shoaling modifications will be introduced by including a bottom friction sink and redistributing the directional energy at shallow-water grid points according to a spline refraction scheme.
(*g*) Preliminary results of a modified Miles-Phillips growth and Maser dissipation have been obtained.

076-08064-720-00

OCEAN REFERENCE SYSTEM

(*c*) J. C. Roque.
(*d*) Development.
(*e*) A modular approach to the design and implementation of an unmanned ocean data collecting station. The design of the payload instrumentation, power supplies, and the buoy modular packaging allows short term experiments at sea for checkout of oceanographic transducers, underwater acoustic devices, and positioning systems, and at the completion of a specific test, is easily re-configured for another measurement task with minimal effort expended in setup and redesign effort. With radio-frequency telemetry capability in both HF and VHF regions and a choice of analog or digital modulation, the platform may allow remote data monitoring from a shore base station or in

deep water work, such as sound propagation, and dispense with the need for a receiving ship. The modular approach is extended to the flotation capsule to comply with desired sea motion characteristics.

LOCKHEED-GEORGIA COMPANY, Advanced Flight Sciences, Department 72-74, Marietta, Ga. 30060. Mr. B. H. Little, Jr., Department Manager.

077-08065-010-15

THREE-DIMENSIONAL TURBULENT BOUNDARY LAYERS

(*b*) U.S. Army, NASA.
(*c*) Dr. John F. Nash, Program Leader.
(*d*) Basic and applied theoretical research.
(*e*) Development of theoretical methods for calculating three-dimensional turbulent boundary layers associated with the passage of fluid over a body of arbitrary geometry. Both steady and unsteady flows are considered, and a variety of surface conditions (e.g., stationary or nonstationary surfaces) can be treated. Numerical methods are used to integrate the partial differential equations of motion and continuity in a three-dimensional domain. The turbulent Reynolds stresses are determined from a parallel numerical integration of rate equations which model the transport of turbulent kinetic energy, or of some other attribute of the turbulence.
(*g*) Boundary-layer calculations have been done both for idealized and practical flow situations–underwater missiles, finite wings, helicopter rotors, wind-tunnel walls, etc. Comparisons have been made with available experimental data.
(*h*) **The Calculation of Three-Dimensional Turbulent Boundary Layers in Incompressible Flow,** J. F, Nash, *J. Fluid Mech.* **37,** p. 625, 1969.
Three-Dimensional Turbulent Boundary Layers, J. F. Nash, V. C. Patel, SBC Tech. Books, Atlanta, 1972.

LOUISIANA STATE UNIVERSITY AND A and M COLLEGE, Department of Agricultural Engineering, Baton Rouge, La. 70803. Eddie A. Landry, Instructor.

078-05915-810-00

FACTORS AFFECTING RUNOFF ON SMALL AGRICULTURAL WATERSHEDS IN LOW, FLAT, ALLUVIAL AREAS

(*b*) Louisiana Agricultural Experimentation Station.
(*d*) Field investigation.
(*e*) Rainfall, runoff, and soil moisture are being measured (on an event basis) on a 50-acre graded watershed (approximately 0.3 percent), located on the Mississippi River alluvial flood plan. The studies' objectives are to determine prediction equations for peak runoff rate and total volume of runoff as a function of rainfall characteristics, soil infiltration, and vegetative cover.
(*g*) Soil infiltration rate equations (as function of time) have been experimentally derived for the two watershed soil types using large ring infiltrometers. Twenty-four rainfall-runoff events have been processed and the information stored in printed and graphical form through utilization of the digital computer.

LOUISIANA STATE UNIVERSITY AND A and M COLLEGE, Coastal Studies Institute, Baton Rouge, La. 70803. Dr. W. G. McIntire, Director.

080-07408-460-20

BOUNDARY-LAYER METEOROLOGICAL INVESTIGATIONS IN THE COASTAL ZONE

(*b*) Geography Programs, Office of Naval Research.
(*c*) Dr. S.-A. Hsu, Asst. Professor.
(*d*) Theoretical and field investigation; basic and applied research.
(*e*) From a dynamical meteorological point of view, the coastal region is one type of transitional zone in which the air flow is continuously readjusting itself to a new set of boundary conditions across the shoreline. The line of separation between land and water constitutes a discontinuity in terms of the roughness of the underlying surface, as well as of heat and moisture distribution. There are many deficiencies at present in knowledge of the processes involved. The objective of the project is to provide a basic understanding of heat, moisture, and wind profiles in the coastal zone. The implications of this study are to improve the understanding of wind stress and surface roughness at the air-sea interface of coastal water; of the internal boundary layer of coastal wind systems; and of aerodynamic roughness criteria in aeolian sand transport.
(*h*) **Coastal Air-Circulation System: Observations and Empirical Model,** S.-A. Hsu, *Monthly Weather Review* **98,** 7, pp. 487-509, July 1970.
The Shear Stress of Sea Breeze on a Swash Zone, S.-A. Hsu, *Proc. 12th Conf. Coastal Engrg., ASCE* **1,** Sept. 1970, Washington, D.C., pp. 243-255.
Measurement of Shear Stress and Roughness Length on a Beach, S.-A. Hsu, *J. Geophys. Res.* **76,** 12, pp. 2880-2885, Apr. 1971.
Wind Stress Criteria in Eolian Sand Transport, S.-A. Hsu, *J. Geophys. Res.* **76,** 35, pp. 8684-8686, Dec. 1971.
Heat and Water Balance Studies on Grand Cayman, S.-A. Hsu, *Caribbean J. Sci.* **12,** 1-2, pp. 9-22, June 1972.

LOUISIANA STATE UNIVERSITY AND A and M COLLEGE, School of Engineering, Baton Rouge, La. 70803.

081-05711-820-61

STORAGE OF FRESH WATER IN HORIZONTAL SALINE AQUIFERS–A MULTI-WELL SYSTEM

(*b*) La. Water Resources Research Institute.
(*c*) Dr. O. K. Kimbler, Prof., Dept. of Pet. Engrg. and Mr. R. G. Kazmann, Prof., Dept. Civil Engineering.
(*d*) Theoretical and experimental.
(*e*) See WRRC **6,** 4.0157.

081-08066-820-61

EFFECT OF FORMATION DIP ON THE MOVEMENT OF FRESH WATER STORED IN SALINE AQUIFERS

(*b*) La. Water Resources Research Institute.
(*c*) Dr. O. K. Kimbler, Prof., Dept. of Pet. Engineering.
(*d*) Theoretical and experimental.
(*e*) See WRRC **6,** 4.0156.

081-08067-800-61

DIVERTING MISSISSIPPI RIVER WATER TO TEXAS–A PRELIMINARY EVALUATION OF PLANS

(*b*) La. Water Resources Research Institute.
(*c*) R. G. Kazmann, Prof., Dept. of Civil Engineering.
(*d*) Theoretical.
(*e*) See WRRC **6,** 8.0318.

081-08068-620-61

FLOW MODEL STUDIES OF DISPLACEMENT IN ANISOTROPIC AQUIFERS

(*b*) La. Water Resources Research Institute.
(*c*) Dr. W. R. Holden, Assoc. Prof., Dept. of Pet. Engineering.
(*d*) Theoretical and experimental; basic research.
(*e*) See WRRC 6, 2.0750.

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MANHATTAN COLLEGE, Civil Engineering Department, Bronx, N.Y. 10471. Dr. Donald J. O'Connor, Professor, Environmental Engineering and Science Program.

082-07410-860-36

DYNAMIC WATER QUALITY FORECASTING AND MANAGEMENT

(*b*) Environmental Protection Agency.
(*d*) Theoretical, applied research.
(*e*) Development of mathematical models and analysis techniques for the prediction of the effects of various control measures on water quality in natural waters.
(*g*) Mathematical modeling of population dynamics in the Potomac Estuary, development and verification of Onondaga Lake thermocline model, major inorganic ion model, phytoplankton-zooplankton dissolved oxygen model.
(*h*) **Recurrent Relations for First Order Sequential Reactions in Natural Waters,** *Water Resour. Res.* **8,** 1, Feb. 1972.
A Dynamic Model of the Phytoplankton Population in the Sacramento-San Joaquin Delta, in *Non-Equilibrium Systems in Natural Water Chemistry*, Advances in Chem. Series, No. 106, ACS, Washington, D.C., 1971.

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MARTIN MARIETTA CORPORATION, Research Institute for Advanced Studies, 1450 South Rolling Road, Baltimore, Md. 21227. Mr. Kenneth Jarmolo, Director of RIAS.

083-08069-010-26

AERODYNAMICS–BOUNDARY LAYER

(*b*) Air Force Office of Scientific Research (in part).
(*c*) Dr. K. C. Wang.
(*d*) Theoretical; applied research.
(*e*) Development of numerical methods for exact calculations of three-dimensional laminar boundary layers and to examine thereby the nature of such viscous flows, and in particular to study laminar flow near separation.
(*g*) Solutions have been obtained for the boundary layer in the plane of symmetry of an ellipsoid of revolution at angle of attack which has allowed examination of some aspects of separation. A general program for the three-dimensional boundary layer has been written.
(*h*) **Further Investigation of Three-Dimensional Boundary Layer Near the Symmetry Plane of an Inclined Body of Revolution,** K. C. Wang, presented at the APS Mtg., Nov. 1971; also *RIAS TR-71-14c*, Sept. 1971.
On the Determination of the Zones of Influence and Dependence for Three-Dimensional Boundary Layer Equation, K. C. Wang, *J. Fluid Mech.* **48,** pp. 397-404, July 1971.
Separation Patterns of Boundary Layer Over An Inclined Body of Revolution, K. C. Wang, *AIAA Paper No. 71-130*, Jan. 1971.
Three-Dimensional Boundary Layer Near the Plane of Symmetry of a Spheroid at Incidence, K. C. Wang, *J. Fluid Mech.* **43,** pp. 187-209, Aug. 1971.

083-08070-540-26

LIFTING AERODYNAMIC SYSTEM

(*b*) Air Force Office of Scientific Research (in part).
(*c*) Dr. P. F. Jordan.
(*d*) Theoretical; applied research.
(*e*) Development of exact methods of lifting surface analysis to obtain better engineering analytic methods and to allow calculation of flow behind such surfaces.
(*g*) An exact lifting surface solution has been found and generalized.
(*h*) **Wing-Edge Pivot Points in Subsonic Lifting Surface Analysis,** P. F. Jordan, *AFOSR-TR-69-3037;* also *RIAS TR 69-17c*, Nov. 1969.
The Parabolic Wing Tip in Subsonic Flow, P. F. Jordan, *AIAA Paper No. 71-10;* also *AFOSR-TR-71-0075*, Jan. 1971.
Span Loading and Wake Formation, P. F. Jordan, *AFOSR-TR-70-2873;* also *RIAS TR 70-12c*, Dec. 1970. AF/Boeing Aircraft Wake Turbulence Symp., Seattle, Sept. 1970. Also Plenum Press, pp. 207-277, 1971.
Complete Solution for Lifting Wings with Parabolic Tips, P. F. Jordan, *RIAS TR 72-04c*, Mar. 1971.

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UNIVERSITY OF MARYLAND, Department of Civil Engineering, College Park, Md. 20742. Dr. R. M. Ragan, Department Chairman.

084-08071-370-47

DESIGN OF SUBSURFACE DRAINAGE FOR HIGHWAYS

(*b*) Federal Highway Administration; Md. State Highway Administration.
(*c*) Dr. Y.M. Sternberg.
(*d*) Theoretical and experimental; applied research.
(*e*) Investigation of fluid flow through a horizontal crack in a highway to subbase material. Determination of vertical and horizontal permeabilities of dense grade aggregates.
(*g*) Experimental data for flow through a crack agrees with theoretical values. Analysis of flow through subbase indicates permeability values are too low for adequate drainage.
(*h*) **Design of Subsurface Drainage for Highways,** Y. M. Sternberg, *Dept. of Civil Engrg. Rept. 41*, Univ. of Md., Aug. 1969.

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UNIVERSITY OF MARYLAND, Institute for Fluid Dynamics and Applied Mathematics, College Park, Md. 20742. Dr. L. T. Crane, Institute Director.

085-08072-130-50

TWO-PHASE FLOW OF A MIXTURE OF A FLUID AND SMALL SOLID PARTICLES

(*b*) National Aeronautics and Space Administration.
(*c*) Dr. S. I. Pai, Research Professor.
(*d*) Theoretical studies of two-phase flow.
(*e*) The fundamental equations of two-phase flow of a mixture of a gas and small solid particles are discussed from the two-fluid theory of continuum point of view. Some insights about the pseudo-fluid of solid particles were obtained. The fundamental equations were numerically solved for the case of lunar ash flow.
(*h*) **A Critical Review of the Fundamental Equations of a Mixture of a Gas and Small Solid Particles,** S. I. Pai, *Z. Flugwiss.* **19,** 1971, Heft 8/9, pp. 353-360.
One-Dimensional Lunar Ash Flow With and Without Heat Transfer, S. I. Pai, T. Hsieh, *IFDAM Tech. Note BN-718*, Univ. of Md., Nov. 1971.
Lunar Ash Flows–The Isothermal Approximation, S. I. Pai, T. Hsieh, J. A. O'Keefe, to be published in *J. Geophys. Res.*

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Civil Engineering, Ralph M. Parsons Laboratory of

Water Resources and Hydrodynamics, Cambridge, Mass. 02139. Donald R. F. Harleman, Laboratory Director.

Requests for publications should be addressed to the Laboratory Director.

086-04648-400-36

A TIDAL-TIME NUMERICAL MODEL FOR ESTUARINE WATER QUALITY PREDICTION

(*b*) Environmental Protection Agency (Water Quality Office).
(*c*) Professor D. R. F. Harleman.
(*d*) Theoretical; basic research (Doctoral thesis).
(*e*) To formulate and obtain numerical solutions to the one-dimensional mass transfer equation, including the temporal and spatial variation of tidal velocity and dispersion terms, in a variable area estuary. The solution for concentration distribution for conservative and nonconservative substances, is to be obtained by a finite-difference scheme.
(*f*) Completed.
(*g*) The mathematical model involves a simultaneous solution of the continuity, momentum and mass transfer equations in an implicit finite difference form. The continuity and momentum equations are formulated with appropriate initial and boundary conditions for the tidal motion. The instantaneous values of water surface elevation and tidal velocity form the input to the conservation of mass equation for a non-conservative substance. Non-linear tidal terms are retained in the momentum equation and any number of discrete inflows of pollutant may be introduced into the mass transfer equation. The dispersion term is related to the tidal velocities in the portion of estuaries above the limit of salinity intrusion. Within the salinity intrusion region the dispersion term is obtained from observed salinity distributions. Agreement has been obtained between calculated and observed concentration distributions for dye dispersion tests in the upper Potomac and James estuaries and for salinity intrusion in the Delaware estuary.
(*h*) **Numerical Model for Estuarine Water Quality Prediction,** D. R. F. Harleman, C. H. Lee, *Boston Section, IEEE, 71-C-51-NEREM*, Part 1, 1971.

086-05119-400-87

TIDAL, SALINITY AND SEDIMENTATION PROBLEMS IN LAKE MARACAIBO CHANNEL, VENEZUELA

(*b*) M.I.T. Inter-American Program in Civil Engrg.; in collaboration with the Instituto Nacional de Canalizaciones and the Universidad del Zulia, Venezuela.
(*c*) Professor A. T. Ippen.
(*d*) Basic research; field investigations.
(*e*) Mathematical model development for two-dimensional velocity and salinity regimes in tidal flow. Purpose of field investigation is to determine the sources and motion of sediment and the time and spatial salinity distribution within the Maracaibo estuary in Venezuela, and to utilize this information for designing remedial works in order to reduce shoaling in the Maracaibo Navigable Channel and control salt water intrusion into Lake Maracaibo.
(*g*) Various methods have been explored to model mathematically the velocity and salinity variations over the depth of a channel for given fresh water flows. Initially time averaged conditions over a tidal cycle are determined. Appropriate boundary conditions are given by other one-dimensional studies. At a later state time-dependent variations of velocity and salinity will be modeled.
(*h*) **Mathematical Model of the Maracaibo Estuary,** J. Fisher, R. Nava, R. H. Cross, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 136*, Feb. 1971.

086-05544-440-36

THERMAL STRATIFICATION AND WATER QUALITY IN LAKES AND RESERVOIRS

(*b*) Environmental Protection Agency (Water Quality Office).
(*c*) Professor D. R. F. Harleman.
(*d*) Experimental and analytical; basic research (Doctoral thesis).
(*e*) Development of analytical methods for the prediction of the seasonal distribution of temperature, B.O.D. and dissolved oxygen in lakes and reservoirs with horizontal stratification.
(*f*) Completed.
(*g*) A theory for the yearly cycle of vertical temperature distribution for a lake has been developed which predicts the formation of a surface mixed layer of varying temperature and depth. Experiments were conducted in a laboratory tank using insolation supplied by mercury-vapor and infrared lamps. Comparisons with field observations in lakes were also made. A mathematical model has been developed which predicts the yearly cycle of temperature distribution within a reservoir and the outlet water temperature. The model accounts for heat input from inflowing streams and solar radiation and heat output from evaporation, radiation at the surface and at the reservoir outlet. The mathematical model was verified by comparison with temperature observations in a laboratory reservoir having artificial insolation and with field data obtained during a full year of operation of Fontana Reservoir (TVA). A water quality model has been coupled with the temperature distribution model to predict the B.O.D. and D.O. distribution both within the reservoir and at the outlet. Comparisons with a limited amount of field data have been made in Fontana Reservoir.
(*h*) **A Predictive Model for Thermal Stratification and Water Quality in Reservoirs,** M. Markofsky, D. R. F. Harleman, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 134*, Jan. 1971, also published by E.P.A., W.Q.O., *Water Poll. Control Res. Series 16130 DJH.*
Prediction of the Annual Cycle of Temperature Changes in a Stratified Lake or Reservoir: Mathematical Model and User's Manual, P. J. Ryan, D. R. F. Harleman, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 137*, Apr. 1971.

086-05823-220-54

TURBULENCE STRUCTURE OF FLOW IN ROUGH POROUS CONDUITS

(*b*) National Science Foundation.
(*c*) Professors L. W. Gelhar, A. T. Ippen.
(*d*) Experimental and theoretical; basic research (Master's and Doctoral theses).
(*e*) The role of turbulence in sediment transport mechanics is being investigated through observations of turbulence structure near rough porous boundaries. Experiments are being made in a ten-inch diameter air flow facility using hot-wire anemometry.
(*g*) Detailed measurements of turbulence in a conduit roughened with 0.13 inch diameter spheres have been completed. The influence of boundary porosity is now being investigated in a 12-inch diameter pipe with a 1-inch thick layer of porous material on the inside of the pipe. Pipes with granular porous boundaries are also being investigated. A theoretical analysis of the effects of boundary porosity has been developed. Very substantial increases in flow resistance and turbulence intensity are produced by the porous boundary. Tracer techniques are currently being used to observe the velocity field in the porous boundary. The effects of undular porous boundaries are currently being studied analytically and experimentally.

086-06413-420-20

SURFACE WAVE STUDIES

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Professor C. C. Mei.
(*d*) Theoretical; basic research (Doctoral thesis).
(*e*) Wave forces on a docklike structure with elliptical plan form. Oscillation in harbors.

(*g*) Wave force on a floating dock or "supertanker" with an elliptical plan form is being computed. The elliptic geometry allows one to investigate the effects of geometrical ratios, angle of wave incidence, etc. Results are of use to large ocean structures and ships. Extensive computations involving Matheiu functions are underway. Oscillation in harbors is being investigated for the case where the breakwaters protrude outward from a straight coastline. The effects of diffraction change the response characteristics inside the harbor. Circular harbors are being computed.

(*h*) **Radiation and Scattering of Water Waves by Rigid Bodies,** J. L. Black, C. C. Mei, M. D. G. Bray, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Staff Pub. No. 199*, Mar. 1971.

Scattering and Radiation of Gravity Waves by an Elliptical Cylinder, H. S. Chen, C. C. Mei, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 140*, Aug. 1971.

086-06421-810-33

OPTIMUM LINEAR SYNTHESIS IN URBAN HYDROLOGY

(*b*) Office of Water Resources Research, Dept. of the Interior.
(*c*) Professor P. S. Eagleson.
(*d*) Theoretical; basic research (Master's and Doctoral theses).
(*e*) Development of a digital computer simulation of surface runoff on urban catchments.
(*f*) Completed.
(*g*) A distributed, finite-element type simulation of surface runoff is developed for digital computer application. The simulation is used to investigate analytical errors due to lumping of distributed systems, analytical errors due to the assumption of linear behavior, experimental errors due to sampling of areally variable rainfall, and to develop an optimum linear model for use in hydraulic design.

086-06422-740-33

A PROBLEM-ORIENTED LANGUAGE FOR HYDROLOGIC ANALYSIS

(*b*) Office of Water Resources Research, Dept. of the Interior.
(*c*) Professors F. E. Perkins, B. M. Harley.
(*d*) Theoretical; basic and applied research (Master's and Doctoral theses).
(*e*) Development of a problem-oriented computer language for a variety of hydrologic analyses including steady and unsteady open channel hydraulics, hydrologic data analysis, and rainfall-runoff processes.
(*g*) Numerical procedures for steady and unsteady open-channel flow problems have been the subject of detailed error analysis leading to the establishment of criteria for adoption of a method and selection of optimum increment sizes.

086-07415-700-44

OPERATIONAL AND RESEARCH USES OF RADAR IN HYDROLOGY

(*b*) National Severe Storms Laboratory, NOAA.
(*c*) Professor P. S. Eagleson.
(*d*) Theoretical and field investigation; basic research (Doctoral thesis).
(*e*) The value of better rainfall information in flood forecasting, water yield and other hydrologic problems is to be determined. The advantages of using radar instead of or in conjunction with raingages is being examined.
(*f*) Completed.
(*g*) Radar is most effective in measuring spatially varying precipitation over large areas, but is relatively inaccurate in determining point rainfall intensities. Raingages require dense networks in order to determine areal variability. The conjunctive use of radar and raingages is found to be potentially beneficial in improving precipitation measurements. A simulation of catchment response to areally distributed rainfall is used, with a stochastic simulation of the rainfall and with the known accuracy of various rainfall measuring systems, to determine under what circumstances the use of weather radar leads to improved flood forecasting.
(*h*) **Evaluation of Radar and Raingage Systems for Flood Forecasting,** W. M. Grayman, P. S. Eagleson, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 138*, Aug. 1971.

086-07416-390-38

MULTIPLE OBJECTIVE ANALYSIS OF THE BIG WALNUT PROJECT

(*b*) Joint Water Resources Council-Laboratory Project.
(*c*) Professor D. C. Major.
(*d*) Applied research.
(*e*) Multiple objective public expenditure theory is applied to a Corps of Engineers proposed project.
(*g*) A net benefit transformation curve for national income and acres of ecological area has been derived.

086-07419-220-00

THE RELATIVE CONCENTRATIONS OF SUSPENDED SEDIMENT IN TURBULENT STREAMS

(*c*) Professor A. T. Ippen.
(*d*) Theoretical and experimental; basic research (Doctoral thesis).
(*e*) Definition of interaction of turbulent free surface shear flow with sedimentary particles in suspension.
(*g*) A special tilting flume, 64 ft. long, 18 in. wide and 10 in. deep, recirculating the sediment-liquid mixture in various concentrations is available for this research. The discharge can be varied up to 3.5 cfs. Measurements of sediment concentrations and of velocity distributions are made in order to explore the validity of semi-theoretical relations for the sediment related modifications of the velocity profiles and the absolute suspended load.
(*h*) **A New Look at Sedimentation in Turbulent Streams,** 1971 John R. Freeman Lecture by Arthur T. Ippen, *J. Boston Soc. Civil Engrs.* **58**, 3, July 1971.

086-07421-870-00

MANAGEMENT ASPECTS OF THERMAL POLLUTION

(*b*) Urban Systems Laboratory, M.I.T.
(*c*) Professor D. H. Marks.
(*d*) Theoretical; applied research.
(*e*) Optimal investment models are described for choosing location and equipment for thermal power generation subject to economic and environmental constraints. Models are designed to give sensitivity information and an approximation of the costs to meet stream temperature standards.
(*g*) Optimal investment models have been proposed and are in a development stage.
(*h*) **Location of Thermal Generating Facilities Under Environmental Constraints,** G. Jirka, D. Marks, *M.I.T., Urban Systems Lab. Rept. 71-1*, Feb. 1971.

086-07423-420-11

WATER-WAVE INTERACTION WITH COASTAL STRUCTURES

(*b*) Coastal Engrg. Research Center, U.S. Army Corps of Engineers.
(*c*) Professors R. H. Cross III, A. T. Ippen.
(*d*) Theoretical and experimental; applied research (Master's and Doctoral theses).
(*e*) The study is concerned with the partial reflection and transmission of waves through permeable breakwaters. Extensive experiments have been carried out in th wave flume of the laboratory on idealized homogeneous odels and on non-homogeneous, standard rubble-mound breakwater configurations.
(*f*) Completed.
(*g*) Water-wave reflection and transmission at various configurations of rubble-mound breakwaters were studied theoretically and verified experimentally. The theory in-

cludes a method of accounting for non-homogeneous media properties by solving for an equivalent homogeneous case. A separate study dealt with the wave transmission by overtopping of impermeable breakwaters of standard configurations. An approximate theoretical approach based on conservation of energy was developed and found to correlate well with experimental results from the present and previous investigations. Experiments were carried out with three different permeable and homogeneous models of rectangular cross-section of different sizes to determine scale-effects for reflection and transmission coefficients. The theoretical expressions were found to overestimate the prototype reflection coefficients and to underestimate the transmission coefficients from the smallest to the largest size of the experimental breakwaters.

(*h*) **Scale Effect in Rubble Mound Breakwaters,** K. W. Wilson, *M. S. Thesis*, M.I.T., Dept. of Civil Engrg., June 1971.
Wave Transmission by Overtopping, R. H. Cross, C. K. Sollitt, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Tech. Note No. 15*, July 1971.
Wave Reflection and Transmission at Permeable Breakwaters, C. K. Sollitt, *Ph.D. Thesis*, M.I.T., Dept. of Civil Engrg., Feb. 1972.

086-07425-820-75

LONG ISLAND GROUNDWATER HYDROLOGY

(*b*) N.Y. State Dept. of Health and the County of Suffolk through Holzmacher, McLendon and Murrell.
(*c*) Professors L. W. Gelhar, D. R. F. Harleman.
(*d*) Experimental and theoretical; applied research (Master's and Doctoral theses).
(*e*) A vertical Hele-Shaw model is being used to simulate the unsteady aquifer response and a salt water intrusion under conditions of increased pumpage.
(*g*) Model simulations of water table response and salt water intrusion have been obtained for alternative methods of groundwater utilization on Long Island. Analytical predictions of salt water intrusion and dispersive mixing between the fresh and salt water have been developed. The motion of contaminants in the aquifers is also being investigated.
(*h*) **Seawater Intrusion in Layered Aquifers,** M. A. Collins, L. W. Gelhar, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Staff Pub. No. 209*, Aug. 1971.

086-07426-420-54

EFFECTS OF TOPOGRAPHY ON STORM OR EARTHQUAKE GENERATED WAVES

(*b*) National Science Foundation.
(*c*) Professors C. C. Mei, A. T. Ippen.
(*d*) Theoretical; basic research (Doctoral thesis).
(*e*) Harmonic generation in shallow waters, edge wave generation, friction loss at breakwaters.
(*g*) A number of theoretical problems which centered on the nonlinearity of wave phenomena in coastal waters are under study. First an analytical theory has been completed on the secondary crest generation in shallow waters. The viewpoint of resonant exchange of energy between harmonics is explored along the line similar to nonlinear optics. Simple experiments have been performed to check the theory. Secondly the resonant excitation of edge wave on a straight sloping beach is investigated. The radiation stresses induced by short sea swells is seen to be capable of exciting edge waves of long periods. A rather realistic model accounting for the shoaling of short waves is taken. Thirdly the effect of flow separation at sharp tips of a breakwater is shown to produce harmonic distortion of the incident waves. In the case of orifices with different loss characteristics when the flow reverses direction, a net current is shown to be possible which may be useful for channel flushing.
(*h*) **Boundary Layer Effects in Water Waves,** L. F. Liu, *M. S. Thesis*, M.I.T., Dept. of Civil Engrg., Sept. 1971.
Harmonic Generation in Shallow Water Waves, C. C. Mei, U. Unluata, *Proc. Advanced Seminar on Water Waves on Beaches*, Mathematics Research Center, Univ. of Wisconsin, Oct. 1971, Academic Press.

086-08073-420-11

MASS TRANSPORT IN WATER WAVES

(*b*) Coastal Engrg. Research Center, U.S. Army Corps of Engineers.
(*c*) Professor C. C. Mei.
(*d*) Experimental and theoretical; basic research (Master's and Doctoral theses).
(*e*) Mass transport by waves in a standing wave system or in the neighborhood of a sea wall. The velocity distribution in a wave tank. Relation to sand transport by waves.
(*g*) Theoretical) The oscillation in water waves induces Reynolds stress in the fluid which in turn gives rise to a steady current at the second order. This net drift produces a transport of fluid particles and suspended sediments as well. Beginning from a Lagrangian description the general formula of mass transport in the boundary layer near a solid bottom is derived. Special cases treated are partially reflected waves and obliquely incident and reflected waves. The effects of reflection coefficient and of angle of incidence on the boundary layer structure and the relevance to bed load movement on the sea bottom are studied. For sufficiently large amplitudes the steady current has a double layer structure near a solid boundary. Calculations are also done for the two-dimensional mass transport in the cross-section of a wave tank.
Experimental: Mass transport velocity profile in a progressive wave is measured by dye tracers and neutrally buoyant particles. Sediment movement patterns under waves are recorded and correlated with theoretical variation of mass transport velocity near the bottom. Study is of importance in understanding the formation of offshore sand bars.
(*h*) **The Non-Linear Evolution of Stokes Waves in Deep Water,** V. H. Chu, C. C. Mei, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Staff Pub. No. 202*, May 1971.

086-08074-870-10

PREDICTIVE MODEL AND DESIGN CRITERIA FOR COOLING PONDS

(*b*) Hydrologic Research Center, U.S. Army Corps of Engineers.
(*c*) Professor D. R. F. Harleman.
(*d*) Theoretical and experimental; basic research (Doctoral thesis).
(*e*) Development of analytical methods for the prediction of circulation patterns and heat dissipation in cooling ponds for the general case in which temperature gradients exist in both horizontal and vertical directions.
(*g*) Experiments are being conducted in a 25 ft. × 40 ft. laboratory cooling pond. Surface heat dissipation coefficients have been evaluated under laboratory conditions. Field data from the Hazelwood cooling pond (Australia) is being analyzed.

086-08075-870-36

PREDICTION OF THE TEMPERATURE FIELD PRODUCED BY THE SURFACE DISCHARGE OF HEATED WATER

(*b*) Environmental Protection Agency (Water Quality Office).
(*c*) Professors D. R. F. Harleman, K. D. Stolzenbach.
(*d*) Theoretical and experimental; basic research (Doctoral thesis).
(*e*) Development of analytical methods for the prediction of the three-dimensional temperature distribution resulting from the discharge of heated water at the surface of a large body of water.
(*g*) The temperature distribution in the ambient body of water is controlled by the initial densimetric Froude number of the surface discharge channel, the ratio of discharge channel depth to width, the rate of surface heat dissipation, the

bottom slope and the cross currents in the receiving water. The theory considers horizontal and vertical entrainment of ambient water into the discharge jet. The vertical entrainment is a function of the local vertical stability and the buoyancy of the heated discharge increases lateral spreading. The theory contains no adjustable parameters and good agreement was obtained in comparison with measurements in the laboratory. A user's manual for the computer program is in preparation.

(*h*) **An Analytical and Experimental Investigation of Surface Discharges of Heated Water,** K. D. Stolzenbach, D. R. F. Harleman, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 135*, Feb. 1971; also published by EPA, WQO, *Water Poll. Control Res. Series 16130 DJU.*

086-8076-870-75

SUBMERGED DIFFUSERS FOR THERMAL DISCHARGES IN COASTAL WATERS

(*b*) Stone and Webster Engrg. Corporation and Long Island Lighting Company.
(*c*) Professors D. R. F. Harleman, K. D. Stolzenbach.
(*d*) Experimental and theoretical; basic and applied research (Master's theses).
(*e*) Design and prediction of the near-field temperature distribution for submerged, multi-port diffusers in coastal waters. Temperature criteria prescribe a maximum temperature rise of1-1/2 °F at the water surface. Studies are concerned with two power plant sites on the south shore of Long Island Sound, the proposed Shoreham nuclear power station and the expansion of generating capacity at the Northport Station.
(*g*) Studies for the Shoreham station have been completed. Undistorted models at scales of 1/20, 1/40 and 1/100 were tested to determine near-field temperature distributions for two- and three-dimensional multi-port diffuser configurations in shallow (15-20') water. Vertical temperature profiles indicated that fully mixed conditions were obtained downstream of the diffuser. The diffusers were tested under various steady currents in the receiving water. In addition, unsteady current tests were made to simulate the effect of the changing magnitude and direction of the prototype tidal currents. Studies for the Northport station are underway. Emphasis is on the development of design criteria for multi-port diffusers in water of intermediate depth (25-40') to define conditions under which either a vertical temperature stratification or a fully mixed temperature field will be produced. Analytical studies are concerned with the application of potential flow theory in which the diffuser is represented by a series of dipoles.
(*h*) **A Study of Submerged Multi-Port Diffusers for Condenser Water Discharge with Application to the Shoreham Nuclear Power Station,** D. R. F. Harleman, G. Jirka, K. Stolzenbach, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 139*, Aug. 1971.
Heat–The Ultimate Waste, *Technology Review* **74**, 2, Dec. 1971.

086-08077-870-75

MODEL STUDIES FOR COOLING WATER DISCHARGE INTO THE CAPE COD CANAL

(*b*) Stone and Webster Engrg. Corp., Montaup Electric Co. and Canal Electric Company.
(*c*) Professors D. R. F. Harleman, J. D. Ditmars.
(*d*) Experimental; applied research.
(*e*) Expansion of generating capacity at the Canal Plant, located near the eastern end of the Cape Cod Canal, requires the design of a new condenser water discharge structure. The heated water discharge is constrained with respect to maximum surface temperatures, maximum surface velocity and physical location in order to protect the marine environment and to ensure no navigational hazards.
(*f*) Completed.
(*g*) Model tests were made for various configurations of submerged-slot diffuser pipes. In the proposed design, the slot diffuser is laid along the slope of the canal bank parallel to the axis of the canal. The discharge is directed vertically upward and the slot width and length were determined to satisfy the surface temperature and velocity criteria. Tests were conducted with simulation of both steady and unsteady tidal currents in the canal.
(*h*) **Investigation of a Submerged, Slotted Pipe Diffuser for Condenser Water Discharge from the Canal Plant, Cape Cod Canal,** D. R. F. Harleman, G. Jirka, E. E. Adams, M. Watanabe, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Rept. No. 141*, Oct. 1971.

086-08078-870-73

THERMAL AND ENVIRONMENTAL STUDIES FOR AN OFFSHORE NUCLEAR GENERATING STATION

(*b*) Public Service Electric and Gas Company, N.J.
(*c*) Professors D. R. F. Harleman, C. C. Mei, O. S. Madsen.
(*d*) Experimental and analytical, basic and applied research.
(*e*) Pertinent features of the offshore site are a breakwater enclosure and associated facilities for intake and discharge of condenser cooling water. The initial phase of the program is concerned with the application of existing analytical and experimental knowledge to engineering and environmental problems associated with heat dissipation and wave action at the offshore site. This includes preliminary prediction for temperature fields for alternative thermal discharge and intake schemes and investigations on breakwater-wave interactions. Specific site-related studies will be developed as design infomation and oceanographic field data become available.

086-08079-870-59

ENVIRONMENTAL IMPACTS OF ENERGY PRODUCTION

(*b*) Office of Science and Technology.
(*c*) Professor D. H. Marks.
(*d*) Applied research.
(*e*) Studies of the technologic, political, economic and locational strategies available for minimizing the environmental impact of electric energy production. Special emphasis on problems of heated water discharges and thermal power station siting.

086-08080-400-44

A PREDICTIVE MODEL FOR UNSTEADY SALINITY INTRUSION IN ESTUARIES

(*b*) Sea Grant Office, National Oceanic and Atmospheric Administration.
(*c*) Professors A. T. Ippen, D. R. F. Harleman, F. E. Perkins, J. D. Ditmars.
(*d*) Theoretical; basic research (Doctoral thesis).
(*e*) Development of a finite difference model to predict time-dependent longitudinal salinity distributions in an estuary. The model couples the continuity and momentum equations for the tidal motion with the one-dimensional mass transport equation for salinity. The model incorporates the time-dependent boundary conditions of tidal range at the ocean end and variable fresh inflows at the head of the estuary and from tributaries along the estuary.
(*g*) The temporal and spatial variation of the longitudinal dispersion coefficient, $E_{x,t}$, is shown to be given by the functional relation $E_{x,t} = K\ \partial s/\partial x + E_T$, where $\partial s/\partial x$ is dimensionless local salinity gradient, E_T is the dispersion coefficient in the non-saline region, and K is a parameter depending on the degree of stratification. A general correlation for K for estuaries covering a wide range of stratification conditions has been obtained. The model has been verified for steady state and transient salinity distribution data for the Delaware, Potomac and Hudson estuaries. A user's manual for the computer program is in preparation.
(*h*) **A Mathematical Model for the Prediction of Unsteady Salinity Intrusion in Estuaries,** M. L. Thatcher, *Ph.D. Thesis*, M.I.T., Dept. of Civil Engrg., Feb. 1972.

086-08081-400-44

WATER QUALITY MODEL FOR A NETWORK OF ESTUARINE CHANNELS

(*b*) Sea Grant Office, National Oceanic and Atmospheric Administration.
(*c*) Professors A. T. Ippen, D. R. F. Harleman, F. E. Perkins, J. D. Ditmars.
(*d*) Theoretical; basic research (Doctoral thesis).
(*e*) An estuary consisting of channels and junctions is modeled mathematically by a network of one-dimensional channels. A finite element model is used for solution of the equations of motion and mass transfer with tidal advection and dispersion included for each branch of the network. These equations are solved, subject to interactions among branches and boundary conditions on the network as a whole, to provide time-dependent concentration distributions for non-conservative water quality parameters.
(*g*) The model is capable of handling interactions among multiple water quality parameters such as temperature, salinity, B.O.D., D.O. and bio-chemical constituents. The ocean boundary condition distinguishes between ebb and flood tide transport of pollutants at the ocean entrance. Data from the James estuary and its tributaries are being used for verification of the model.

086-08082-400-44

A TWO-DIMENSIONAL MATHEMATICAL MODEL FOR SALINITY DISTRIBUTION IN ESTUARIES

(*b*) Sea Grant Office, National Oceanic and Atmospheric Administration.
(*c*) Professors A. T. Ippen, D. R. F. Harleman.
(*d*) Theoretical; basic research (Doctoral thesis).
(*e*) Development of analytical methods to describe the two-dimensional salinity distribution in an estuary which is homogeneous laterally, but non-homogeneous vertically. The initial phase is concerned with time-averages of salinity and velocity over a tidal period. The objective is to provide a better understanding of salinity and sediment transport processes in estuaries.
(*g*) An analytical model has been developed which relates the vertical velocity and salinity profiles to the depth-averaged longitudinal salinity gradient. The model has been successfully tested with both flume and prototype data. Two parameters describing the vertical diffusion of momentum and salt have been determined which correlate well with the large-scale circulation characteristics of the estuaries and flumes studied. When coupled with a one-dimensional salinity distribution model, this analytical technique can indicate the velocity predominance of bottom currents, and thus the shoaling characteristics of the estuary.

086-08083-450-44

THE SEA ENVIRONMENT IN MASSACHUSETTS BAY AND ADJACENT WATERS

(*b*) Sea Grant Office, National Oceanic and Atmospheric Administration.
(*c*) Professors A. T. Ippen, E. L. Mollo-Christensen (Dept. of Meteorology); Professors D. R. F. Harleman, S. F. Moore, J. D. Ditmars, R. C. Beardsley (Dept. of Meteorology), Professor J. M. Edmond (Dept. of Earth and Planetary Sciences).
(*d*) Field studies and theoretical; basic and applied research and instrument development.
(*e*) An interdisciplinary and interdepartmental study with the objective of a comprehensive understanding of the physical environment of the waters of Massachusetts Bay and adjacent waters. Primary emphasis is on the definition and solution of water quality problems. Initially, work is oriented toward methods and instruments for data acquisition and analysis and for integrated system response. The collection of baseline data throughout the Bay and at specific regions of man's intervention into the coastal zone has begun. Increased surveillance of the Bay environment is planned with the eventual development of a model describing the physical environment of Massachusetts Bay.
(*g*) Initial efforts have resulted in the developme computer-compatible instruments of relatively n and of great utility in the coastal zone, a small-l thermograph, a conductivity-temperature-depth a towed thermistor array. These instruments used on M.I.T.'s research vessel R. R. SHROCI exploratory field data, and they will be used in c with on-going chemistry cruises in the Bay. A c program has been initiated with the New Engla um whose research staff has been actively mon water quality of the Boston Harbor area.

086-08084-820-36

ANALYSIS AND PREDICTION OF SUBSURFACI QUALITY

(*b*) Environmental Protection Agency.
(*c*) Professor L. W. Gelhar.
(*d*) Theoretical and experimental; basic research and Doctoral theses).
(*e*) Several aspects of mass transport in porous being explored using mathematical models and experiments. The emphasis is on phenomena wl importance in describing and forecasting gı quality. Mathematical methods of describing l dispersion in general nonuniform flows are bei The effects of density differences in well recharg disposal operation are being simulated. Also in mixing phenomena in unsaturated flows, and tl tive and dispersive mixing process near pumping
(*g*) Analytical solutions of the convective dispersio in nonuniform flows have been obtained usir perturbation methods. Analytical descriptions induced mixing in recharge pumping operations developed and compared with laboratory obser radial flow model. The effects of dispersion on induced mixing are predicted by the mathematic
(*h*) **A General Analysis of Longitudinal Dispersion niform Flow,** L. W. Gelhar, M. A. Collins, *Wa Res.* 7, Dec. 1971.

086-08085-810-00

FLOOD FORECASTING USING RAINFALL STATI

(*c*) Professor P. S. Eagleson.
(*d*) Theoretical; basic research.
(*e*) Development of a physically valid analytical exp flood-frequency in terms of parameters de catchment-stream physiography and the statist rainfall.
(*f*) Completed.
(*g*) Generalized probability density functions of stor and storm rainfall depth, given duration, an as function and an assumed probability density fu runoff-producing area are used, with the stoch tions for maximum direct storm runoff, to probability density funtion of peak streamflow. is used to obtain the classical flood-frequency c explicit function of parameters defining the r tributions and the catchment-stream physiograph
(*h*) **The Stochastic Kinematic Wave,** P. S. Eagleson *Bilateral U.S.–Japan Seminar in Hydrolog* Resources Pub., Ft. Collins, Colo., 1971, pp. 20

086-08086-810-33

FORECASTING AND CONTROL OF URBAN RUNOFF

(*b*) Office of Water Resources Research, Dept. of th
(*c*) Professors P. S. Eagleson, J. C. Schaake, Jr.
(*d*) Basic and applied research (Master's and theses).
(*e*) The purpose of this research is to develop m may be used to forecast and control urban sto Two general subjects are being considered, an evaluation of precipitation information sy hydrologic forecasting, and the development

or urban drainage control. The first topic involves ment of the relative economic value of radar and networks and a combination of both in hydrolog- asting. The second topic involves developing atical models of stochastic relationships between and the response characteristics of urban nts.

benefits from a range of precipitation measuring used for flood warning are determined using simu- r a hypothetical river basin. The optimal configu- the precipitation measuring system is determined nge of economic development. Generalized proba- nsity functions of storm and catchment variables bled as input to a digital simulation of catchment and the flood frequency curve is generated.

on of Radar and Raingage Systems for Flood ing, W. M. Grayman, P. S. Eagleson, *M.I.T., Dept. grg., R. M. Parsons Lab. Water Res. Hydro., Rept. , Aug. 1971.*

on of Hydrologic Frequency Curves, G. LeClerc, J. ake, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. es. Hydro., Rept. No. 142*, Jan. 1972.

70-33

ENT OF URBAN STORM WATER DRAINAGE

f Water Resources Research, Dept. of the Interior.
rs J. C. Schaake, Jr., D. H. Marks.
ical; applied research.
of optimal investment in urban storm drainage net- nd optimal control of systems. Emphasis on build- ble optimal seeking and heuristic algorithms for stu- the sensitivity of solution to various physical ers and policy alternatives.
are in a developmental stage.

10-00

F URBANIZATION ON FLOOD HYDROGRAPHS

or B. M. Harley.
ical; basic research (Bachelor's and Master's

tion of some of the existing catchment-stream to urban areas. Development techniques to allow nodels to handle the particular details of urban

nique for the effective routing of rainfall which is to either pervious or impervious areas has been ped. Stability and convergence criteria for the finite nce scheme used are presented.
of Urbanization on the Runoff Characteristics of Basins in Puerto Rico, R. Bras, *S.B. Thesis*, M.I.T., f Civil Engrg., Dec. 1971.

870-00

G MODELS IN STORM WATER MANAGEMENT

or D. H. Marks.
tical; applied research.
matical models for the investigation of storm water ion and treatment systems. Optimization techniques ed to find system configurations under several dif- objectives and policy constraints. The purpose of nodels is to screen alternatives for more detailed ity and physical simulation studies.

870-00

GE MUNICIPAL SERVICES STUDY (WATER AND WASTE WATER DISPOSAL)

-Mellon Trust.
sor D. H. Marks.
etical; applied research.
of municipal services in an urban context, with idge, Massachusetts, as a case study. Attempt to y problems, objectives, measures of effectiveness, ent technical, economic, political and social constraints for service system. One part of research devoted to water supply and waste water disposal.

(*f*) Completed.
(*h*) **Location Models–A Solid Waste Collection Example,** D. H. Marks, J. S. Liebman, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Staff Pub. No. 205*, Apr. 1971.
Routing for Public Service Vehicles, D. H. Marks, R. Stricker, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Staff Pub. No. 206*, Dec. 1971.

086-08091-870-36

ANALYSIS MODELS FOR SOLID WASTE COLLECTION

(*b*) Environmental Protection Agency, Office of Solid Waste Management.
(*c*) Professor D. H. Marks.
(*d*) Theoretical; applied research.
(*e*) Mathematical models are developed for common processes in solid waste collection including macroscale problems such as selection of locations and technology for transfer and disposal and vehicle selection and routing, crew scheduling, districting and collection policy. Use of such models in the decision-making process is stressed. Case studies for the MDC and Brookline are in process.
(*g*) Development and implementation stage.

086-08092-800-87

WATER RESOURCE DEVELOPMENT IN ARGENTINA

(*b*) Sub-Secretary of State for Water Resources, Argentina.
(*c*) Professors F. E. Perkins, J. C. Schaake, D. H. Marks, D. Major, B. H. Harley, I. Rodriguez-Iturbe.
(*d*) Theoretical and field investigation; applied research and development.
(*e*) Development of a modern multi-objective planning framework for use in river basin planning in Argentine; training of Argentine professionals in the theory and application of planning methods; demonstration of new planning models as applied to a particular basin planning problem in Argentina.
(*g*) A series of models for simulation of economic and physical components of typical basins and for screening of proposed alternatives have been developed. Acquisition and intepretation of data for a case study of the Rio Colorado is progressing. Models are being used to formulate management and investment alternatives. These alternatives are reviewed by political and technical representatives of the provinces. Ultimately the project will provide a set of alternatives that make the best possible contributions toward the relevant economic and social objectives. It will remain for the public decision process in Argentina to choose the preferred alternative.
(*h*) **Integrated Development Plan for the Rio Colorado, Argentina,** W. M. Grayman, et.al., presented at the *7th Amer. Water Resources Conf.*, Washington, D.C., Oct. 1971.
Simulation of the Continuous Snowmelt Process, R. L. Laramie, *M.I.T., Dept. Civil Engrg., R. M. Parsons Lab. Water Res. Hydro., Tech. Rept. 143*, Jan. 1972.

086-08093-390-33

PROJECT EVALUATION: BUDGET CONSTRAINTS

(*b*) Office of Water Resources Research.
(*c*) Professor D. C. Major.
(*d*) Basic and applied research.
(*e*) Budget constraints are analyzed theoretically from a multiobjective standpoint. A shadow price on budget resources for a recent group of federal projects will be calculated.

086-08094-390-80

LAW AND THE SOCIAL CONTROL OF SCIENCE AND TECHNOLOGY

(*b*) National Endowment for the Humanities.
(*c*) Professor M. S. Baram.
(*d*) Curriculum development.

(*e*) Interdisciplinary exploration of social forces–economic, legal, cultural, technical, etc.–which determine applications of science and technology and bring about social side effects. Development of case studies (subject 1.83 in M.I.T. Catalog).
(*g*) Synthesis of descriptive information from numerous sources. Systematic approach and partial development of comprehensive analytical framework. Concurrent development of course structure and contents.
(*h*) **A Fremework for Approaching the Social Control of Science and Technology,** M. S. Baram, D. Ducsik, presented at *AAAS Conf. Panel on Social Control of Science and Technology*, Dec. 1971.

086-08095-880-36

LEGAL AND SOCIAL ASPECTS OF ENVIRONMENTAL QUALITY

(*b*) Environmental Protection Agency, New England Consortium of Universities.
(*c*) Professor M. S. Baram.
(*d*) Curriculum development.
(*e*) See subjects 1.811 and 1.812 in M.I.T. Catalog.
(*g*) Student papers and field research reports on broad range of environmental problems–air and water pollution, land use, noise, decision-making, etc.

086-08096-880-88

INTERNATIONAL ENVIRONMENTAL CONTROL PROGRAM

(*b*) World Health Organization, IBM Foundation, M.I.T. Environmental Laboratory.
(*c*) Professor M. S. Baram.
(*d*) Conceptual (basic research) and early applications.
(*e*) Systematic approach to international environmental problems. Development of analytical fremeworks and infrastructure for planning and decision-making. Applications to be developed for specific environmental problems.
(*g*) Integration of legal, technical and socio-economic considerations into conceptual frameworks for analysis and decision-making. Early applications to problems of mercury and noise pollution.
(*h*) **Chemicals in the Environment–Outline for a Systematic Approach to the Problem,** M. S. Baram, S. P. Mauch, presented at *Organization for Economic Cooperation and Development*, Paris, NR/ENV/71.43.
Outline for a Systematic Approach to Noise Abatement and Control, M. S. Baram, S. P. Mauch, presented at *Congressional Hearings on Noise*, Boston, Oct. 1971.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Meteorology, Cambridge, Mass. 02139. Professor Norman A. Phillips, Department Head.

087-08097-480-54

ANALYSIS OF SUBSYNOPTIC-SCALE PRECIPITATION PATTERNS

(*b*) National Science Foundation; NASA.
(*c*) Dr. Pauline M. Austin.
(*d*) Experimental, basic research.
(*e*) Observations of storms within 200 km of Cambridge, Mass., are made with quantitative radar and rain gauges which have high resolution in time. Data have been accumulated for a number of years and are being analyzed to provide detailed descriptions and statistics of the small-scale structure in storms.
(*h*) **Analysis of the Structure of Precipitation Patterns in New England,** P. M. Austin, R. A. Houze, Jr., *J. Appl. Meteor.*, in press.
Development and Appreciation of a Method for Computing Cumulus Transports, R. A. Houze, Jr., *Ph.D. Thesis*, Dept. Meteor., M.I.T., 1972.

087-08098-480-54

PLANETARY CIRCULATIONS PROJECT

(*b*) National Science Foundation.
(*c*) Victor P. Starr, Project Director.
(*d*) Mainly theoretical.
(*e*) Extensive global meteorological observations are being used to compute the transport and convergence (or divergence) of water vapor in the atmosphere. The results are used to measure the global distribution of the excess of precipitation over evaporation. Various hydrological implications of these processes are being examined. The artificial extraction by dynamic processes of liquid water from (cloudless) air is being studied.
(*h*) **The General Circulation of the Atmosphere and its Effects on the Movement of Trace Substances. Part 2,** R. E. Newell, J. M. Wallace, J. R. Mahoney, *Tellus* **18,** 363-380, 1966.
Diurnal Variations in the Summer Water Vapor Transport Over North America, E. M. Rasmusson, *Water Resour. Res.* **2,** 469-477, 1966.
The Earth's Gaseous Hydrosphere as a Natural Resource, V. P. Starr, D. A. Anati, *Nordic Hydrology* **2,** 65-78, 1971.
Pole-to-Pole Eddy Transport of Water Vapor in the Atmosphere During the IGY, V. P. Starr, J. P. Peixoto, *Archiv f. Meteor..Geof. u.*, 1971.
Pole-to-Pole Water Balance for the IGY from Aerological Data, J. P. Peixoto, *Nordic Hydrology*, in press, 1972.
Studies of Atmospheric Water Vapor by Means of Passive Microwave Techniques, N. E. Gaut, *M.I.T., Res. Lab. of Electronics, Tech. Rept. 467;* also *Ph.D. Dissertation*, M.I.T., 1968.
Pole-to-Pole Moisture Conditions for the IGY, V. P. Starr, J. P. Peixoto, R. M. Kean, *Pure and Appl. Geoph.* **75,** 300-331, 1969.
Water Vapor Balance of the Atmosphere from Five Years of Hemispheric Data, J. P. Peixoto, *Nordic Hydrology* **1,** 120-138, 1970.
Pole-to-Pole Divergence of Water Vapor, J. P. Peixoto, *Tellus* **22,** 17-25, 1970.
Atmospheric Vapor Flux Computations for Hydrological Purposes, J. P. Peixoto, *Proc. RA-VI Working Group on Hydrology, W.M.O.*, held at Geneva, in press, Feb. 1971.
Controlled Atmospheric Convection in an Engineered Structure, V. P. Starr, D. A. Anati, N. E. Gaut, *Nordic Hydrology*, in press, 1971.
Experimental Engineering Procedure for the Recovery of Liquid Water from the Atmospheric Vapor Content, V. P. Starr, D. A. Anati, *Pure and Appl. Geoph.* **86,** 205-208, 1971.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Ocean Engineering, Cambridge, Mass. 92139. Professor Martin A. Abkowitz, Director, Ship Model Towing Tank.

088-06607-520-45

MAINTAINING SHIP SPEED AT SEA-SHIP PERFORMANCE IN A SEAWAY

(*b*) U.S. Maritime Administration.
(*d*) Experimental and theoretical; applied research, development; Masters and Doctoral theses.
(*e*) The broad aspect of improving ship performance in rough seas is being studied by more specific investigations in the following areas. Improvement in model testing techniques for performance prediction and evaluation; improvement and consolidation of theoretical methods for prediction of ship responses in a seaway (responses are displacements, velocities, accelerations, speed loss, structural loading, slamming, etc.) including added resistance in a seaway;

development and application of techniques to predict maximum response in a given seaway; development of consolidated, but extensive computer programs to facilitate the application of these developments into the design process; model investigation of transom stern hulls in a seaway.

(*h*) **Computer Aided Prediction of Seakeeping Performance in Ship Design,** T. A. Loukakis, *Dept. of Naval Arch. and Marine Engrg. Report 70-3*, M.I.T., Aug. 1970.
Seakeeping Performance of Fast Transom Stern Cargo Ships, J. O'Dea, *Dept. of Naval Arch. and Marine Engrg. Report 70-2*, M.I.T.

088-06609-520-21

MAXIMUM MOTIONS AND BENDING MOMENT LOADINGS OF DESTROYERS IN SEVERE SEA STATES

(*b*) U.S. Navy, Naval Ship Res. and Dev. Center.
(*d*) Experimental and theoretical; applied research and development.
(*e*) To use and further develop the technique of generating, in the towing tank, long-time samples of random irregular seas of any specified spectral distribution. The specific model tesing program involves the determination of maximum responses, especially midship bending moment, of destroyer models, with and without large bow sonar domes, in several heavy sea states. Development of the technique involved the building of a unique beach in the towing tank in order to kill wave reflections to allow long time samples, and the generation of purely random seas of given spectral content by means of white noise generator.
(*f*) Completed.
(*h*) **Extreme Wave Heights and Ship Responses in a Seaway,** T. Loukakis, *Dept. of Naval Arch. and Marine Engrg. Rept. No. 70-5*, M.I.T., Mar. 1970.
Experimental Modeling of Seaways, T. Loukakis, O. Oakley, Jr., *Dept. of Naval Arch. and Marine Engrg. Rept. No. 70-6*, M.I.T., Mar. 1970.

UNIVERSITY OF MASSACHUSETTS, School of Engineering, Amherst, Mass. 01002. Dr. K. G. Picha, Dean.

090-02561-810-33

HYDROLOGY STUDIES IN MASSACHUSETTS

(*b*) Office of Water Resources Research and Massachusetts Water Resources Research Center.
(*c*) Professor George R. Higgins, Dept. of Civil Engineering.
(*d*) Experimental; field and laboratory.
(*e*) Primary thrust of the research was toward an evaluation of evaporation losses to be expected in a humid region such as the Northeastern United States. Field studies were performed at Quabbin Reservoir in central Massachusetts; however, results are believed to be applicable over a larger portion of the Northeast than the immediate vicinity of Quabbin Reservoir. Other factors related to watershed yield such as rainfall-runoff relationships, drought effects, demand variations, and hydrologic response of watersheds, were also studied.
(*f*) Completed.
(*h*) **Hydrologic Factors in the Determination of Watershed Yields,** G. R. Higgins, J. M. Colonell, *WRRC Pub. No. 20*, Amherst, Mass., 125 pp., July 1971.

090-06666-430-20

UTILIZATION OF MOBILE BREAKWATER DEVICES TO REDUCE SURFACE MOTIONS OF SUBMERSIBLE VEHICLES FOR DEEP OCEAN ENGINEERING PURPOSES

(*b*) Office of Naval Research.
(*c*) Dr. Charles E. Carver, Jr., Dept. of Civil Engineering.
(*d*) Experimental; applied research.
(*e*) The attenuation characteristics of a pneumatic and hydraulic breakwater used singly as well as in tandem have been investigated in the UMass Fluid Mechanics Laboratory Wind-Generated Wave Facility. Deep water wave spectra upstream and downstream of the breakwaters are measured as well as the power input to both breakwaters. The reduction in mean wave height is used as a measure of wave attenuation. The wind speed is held constant and discharge rates of air and water to the breakwaters are varied. Both devices are submerged to a depth of two feet. The surface current velocities due to the air and water jet action are measured with a midget current meter.
(*f*) Experimental measurements have been completed. Data analysis is currently in progress.
(*g*) A technical report is expected to be completed in July 1972, essentially embodying a Master's thesis.

090-06681-520-20

WIND TUNNEL TESTING OF MARINE VEHICLE COMPONENTS

(*b*) Office of Naval Research.
(*c*) Dr. D. E. Cromack, Dept. of Mechanical and Aerospace Engineering.
(*d*) Basic and applied; theoretical and experimental; Ph.D. thesis.
(*e*) Pressure field associated with a ducted propeller is being investigated analytically and in an open jet wind tunnel.
(*h*) **Ducted Propellers–A Review and Description of Current Investigation,** R. J. Weetman, D. E. Cromack, *Report No. THEMIS-UM-70-1.*

090-06682-540-14

A STUDY OF AIRBORNE TOWED VEHICLE DYNAMICS

(*b*) U.S. Army Research Office.
(*c*) Drs. C. R. Poli, D. E. Cromack, Dept. of Mechanical and Aerospace Engineering.
(*d*) Basic and applied; theoretical and experimental; Masters and Ph.D. theses.
(*e*) Stability of towed bodies including cable effects.

090-07816-440-33

ENVIRONMENTAL FACTORS AFFECTING THE MANAGEMENT OF RESERVOIR WATER QUALITY

(*b*) Office of Water Resources Research and Massachusetts Water Resources Research Center.
(*c*) Dr. Joseph M. Colonell, Dept. of Civil Engineering.
(*d*) Field and laboratory evaluation of theoretical techniques for prediction of reservoir dynamics.
(*e*) The overall objective of this research is to achieve a thorough comprehension of the physical processes which affect the dynamics of a lake or reservoir. Knowledge of the intimate relationship between water quality and water dynamics can then be employed to evolve useful systems of reservoir management. The initial emphasis of this research is on the evaluation and improvement of available techniques for modeling (mathematically) the hydrodynamic and thermodynamic behavior of a large body of water. A major portion of the work is involved with experimental investigations of the complex response of a reservoir to hydrologic and meteorologic influences. Field measurements are being conducted at Quabbin Reservoir in central Massachusetts.

090-07817-430-20

SIMULATION TECHNIQUES FOR DYNAMIC MODELING OF OCEAN ENGINEERING STRUCTURES

(*b*) Office of Naval Research.
(*c*) Dr. Joseph M. Colonell, Dept. of Civil Engineering.
(*d*) Experimental; applied research.
(*e*) Models of simple ocean engineering structures are being tested for their response to wind-generated waves in a laboratory sea wave facility designed by the author in conjunction with another project (06666). The objective is to examine basic similitude relationships for fixed and floating structures in a random seaway. Also under investiga-

tion are certain aspects of air-sea interaction processes which are pertinent to the establishment of valid similitude relationships.

(*h*) **A Wind Wave Research Facility,** J. M. Colonell, *Rept. No. UM-72-2*, Mar. 1972.

Laboratory Modeling of Structural Response to Ocean Wave Excitation, C. A. Clines, J. M. Colonell, *Report No. UM-72-3*, Apr. 1972.

090-07819-410-00

DYNAMICS OF BEACH AND WAVE INTERACTION

(*c*) Dr. Joseph M. Colonell, Dept. of Civil Engineering.
(*d*) Field and laboratory investigation; applied research.
(*e*) Under investigation are techniques for analysis of beach response to wave action. Methods have been developed for automated display of beach profile measurements in support of the analysis of beach and wave interaction.
(*h*) **Effects of Nonuniform Wave Energy in the Littoral Zone,** V. Goldsmith, J. M. Colonell, *Proc. 12th Intl. Conf. on Coastal Engrg., ASCE* **2**, pp. 767-785, Washington, D.C., Sept. 1970.

Computational Methods for Analysis of Beach and Wave Dynamics, J. M. Colonell, V. Goldsmith, *Proc. 2nd Annual Geomorphology Symp.*, Binghamton, N.Y., 38 pp., Oct. 1971.

Characteristics and Effects of Wave Refraction; Monomoy Island, Cape Cod, Massachusetts, V. Goldsmith, J. M. Colonell, *Abstract Vol., 2nd Natl. Coastal and Shallow Water Res. Conf.*, Newark, Del., p. 87, Oct. 1971.

Forms of Erosion and Accretion on Cape Cod Beaches, V. Goldsmith, J. M. Colonell, P. N. Turbide, *Proc. 13th Intl. Conf. on Coastal Engrg.*, Vancouver, B.C., July 1972.

Development of a Coastal Data Bank for the Northeastern United States, J. M. Colonell, V. Goldsmith, P. N. Turbide, *Proc. 24th Intl. Geological Congress*, Montreal, Que., Aug. 1972.

090-08122-700-54

DIRECT MEASUREMENT OF THE VELOCITY GRADIENT IN A FLUID FLOW–AN EXTENSION OF THE HOT WIRE TECHNIQUE

(*b*) National Science Foundation.
(*c*) Dr. R. H. Kirchhoff, Dept. of Mechanical Engineering.
(*d*) Experimental; basic research.
(*e*) The harmonic response of a hot-wire anemometer in forced oscillation is measured with a lock-in amplifier. It is shown theoretically and experimentally that the first harmonic is proportional to the first derivative of the velocity profile. Higher harmonics contain other information, including the second derivative of the velocity profile.
(*h*) **Direct Measurement of the Velocity Gradient in a Fluid Flow,** R. H. Kirchhoff, E. K. Voci. Accepted for publication in AIAA J., 1972.

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MICHIGAN TECHNOLOGICAL UNIVERSITY, Department of Chemistry and Chemical Engineering, Houghton, Mich. 49931. Dr. Lawrence B. Hein, Department Head.

091-08430-020-00

MIXING IN CONTINUOUS FLOW STIRRED TANKS

(*c*) Davis W. Hubbard, Assoc. Professor.
(*d*) Applied research, experimental.
(*e*) The deviation from perfect mixing behavior in continuous flow mixing systems is being measured by the tracer technique. The effects of system geometry, flow rate, and impeller speed are being determined. The experiments are being performed using Newtonian and non-Newtonian fluids.
(*g*) Effects of impeller speed and flow rate have been determined for low Reynolds number operation. A correlation procedure for the data has been developed.
(*h*) **Effect of Geometry and Process Variables** [illegible] **Mixing,** H. Patel, *M.S. Thesis*, Mich. Tech. Un[illegible]

Dimensional Analysis for Imperfect Mixing [illegible] W. Hubbard, H. Patel, *62nd Ann. Mtg., AI*[illegible] *49i*, Washington, 1969.

Hydrodynamic Measurements for Imper[illegible] **Processes: Newtonian Fluids,** D. W. Hubba[illegible] *AIChE J.* **17**, 1387, 1971.

091-08431-020-00

SCALE-UP FOR MIXING SYSTEMS

(*c*) Davis W. Hubbard, Assoc. Professor.
(*d*) Applied research, experimental.
(*e*) Methods for scaling-up mixing systems [illegible] developed using residence time distribution [illegible] in Newtonian and non-Newtonian fluids. The [illegible] sis for the work is on flow regime identific[illegible] dynamic similarity as a scale-up criterion.
(*g*) A method for flow regime identificatio[illegible] developed for impeller agitated continuous [illegible] systems used for processing water soluble p[illegible] tions.
(*h*) **Dynamic Similarity for Imperfect Mixing Pr**[illegible] **Newtonian Fluids,** D. W. Hubbard, F. F. Calv[illegible] (in press).

Imperfect Mixing of Non-Newtonian Fluids, F[illegible] *M.S. Thesis*, Mich. Tech. Univ., 1971.

Scale-Up Studies for a Mixing System in whic[illegible] **Reaction Occurs,** L. C. Wu, *M.S. Thesis*, [illegible] Univ., 1972.

Mixing in Continuous Flow Stirred Tanks, D.[illegible] *M.S. Thesis*, Mich. Tech. Univ., 1972.

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UNIVERSITY OF MICHIGAN, College of Engin[illegible] **partment of Aerospace Engineering,** Ann A[illegible] 48104. Professor R. M. Howe, Department C[illegible]

092-07442-010-20

AN INVESTIGATION OF WALL PRESSURE [illegible] TIONS AND STRUCTURE OF A TURBULEN[illegible] RY LAYER

(*b*) Office of Naval Research, Fluid Dynamics Bra[illegible]
(*c*) Professor William W. Willmarth.
(*d*) Experimental, basic research, Doctoral thesis.
(*e*) Fluctuating velocity and pressure measurem[illegible] beneath turbulent boundary layers. Purpo[illegible] research on turbulence.
(*g*) Study of fluctuating wall pressures benea[illegible] layers with severe transverse curvature in o[illegible] the effect of transverse curvature on turbul[illegible] and wall pressures. Also, measurements have [illegible] of the structure of the Reynolds stress whic[illegible] magnitude very intermittent contributions to [illegible] This work was made possible by use of a digi[illegible] for data reduction.
(*h*) **Wall-Pressure Fluctuations Beneath Turbule**[illegible] **Layers on a Flat Plate and a Cylinder,** W. W[illegible] C. S. Yang, *J. Fluid Mech.* **41**, 1, pp. 47-80, M[illegible]

Structure of the Reynolds Stress Near the W[illegible] marth, S. S. Lu, *AGARD Fluid Dynamics Pan*[illegible] *Mtg. on Turbulent Shear Flows*, London, Sept. [illegible]

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UNIVERSITY OF MICHIGAN, Department of Cl[illegible] **gineering, Sonochemical Engineering Laborato**[illegible] **of Chemical Engineering,** Ann Arbor, Mich. [illegible] H. Scott Fogler, Associate Professor.

093-07444-120-00

CAVITATION IN VISCOELASTIC FLUIDS

(*d*) Theoretical and experimental.

experimental phase of this study we are photogra- collapsing cavities produced by an electric spark in oelastic fluid. A concurrent program is underway to tically model the collapse of these cavities in lastic fluids.
inary results indicate that liquid elasticity can sig- ntly retard the collapse of a spherical void, and in cases produce prolonged oscillatory motion rather atastrophic collapse.

-150-00

HASE MASS TRANSPORT ACCELERATED BY IC STREAMING

etical and experimental.
mental and theoretical study of gas absorption is enhanced by acoustic streaming. Ultrasonic waves parted to thin liquid films in which one film bounda- metal plate and the other boundary is the free inter- t which the absorbing gas enters the film.
xperimental acoustic streaming speeds in these thin ppear to be much greater than any speeds reported theoretically or experimentally. It is believed that icrostreaming phenomenon should greatly enhance ransfer rates into thin liquid films.

-230-00

L REACTIONS IN CAVITATION BUBBLES

etical and experimental.
work concerns a fundamental study on gas phase ons occurring during the collapse phase of an ul- ically induced cavitation bubble in a large body of The initial phases of this work are centered around studied CCl_4-water reactions. It is believed that the mechanism for this reaction during collapse is stood, we will be able to predict what other reactions e acclerated ultrasonically.

TY OF MICHIGAN, College of Engineering, De- of Civil Engineering, Ann Arbor, Mich., 48104. Brater, Professor of Hydraulic Engineering.

-810-60

REDICTION

gan State Highway Dept.; Federal Highway Adminis- n.
sis of field data, basic research.
ll and runoff data from small watersheds in western Michigan are being analyzed to determine in- on capacities and flood hydrograph shapes for the se of predicting the frequency of floods on sheds in various stages of urbanization.
leted.
ds have been developed for relating changes in graph shape and amount of impermeable area to ation density.
Toward A Better Understanding Of Urban Runoff sses, E. F. Brater, *Water Resour. Res.* **4**, 2, Apr. p. 335.
s of Urbanization on Peak Flows, E. F. Brater, S. l, *The Effects of Watershed Changes on Streamflow*, r for Research on Water Resources, Univ. of Texas,

-810-60

-RUNOFF RELATIONS ON URBAN AND RURAL

onmental Protection Agency.
sis of field data, basic research.
ll and runoff data from small watersheds in various of urbanization are being studied to determine the of such factors as size of basin, the amount of im- permeable areas, shape of basin and the nature of the drainage network in storm runoff.
(*g*) Methods are being developed for relating changes in hydrograph shape and amount of impermeable area to population density. A mathematical model has been used to extend the range of the parameters being studied.
(*h*) See 094-05558.

094-06424-420-54

WAVE FORCES ON SUBMERGED STRUCTURES

(*b*) National Science Foundation.
(*d*) Experimental; basic research and application to engineering design.
(*e*) Study of forces on submerged pipe lines.
(*f*) Research completed.
(*g*) Coefficients of drag and virtual mass were determined for pipes of various sizes and positions for various wave heights and wave lengths.
(*h*) Paper presented at *13th Int. Conf. Coastal Engrg.*, July, 1972.

094-06425-210-54

TRANSIENTS IN GAS DISTRIBUTION SYSTEMS

(*b*) National Science Foundation.
(*c*) Professor V. L. Streeter.
(*d*) Theoretical and experimental (field); basic research, for Doctor's degree.
(*e*) Application of characteristics method for control of gas distribution systems.
(*h*) **Network System Transient Calculations by Implicit Method,** E. B. Wylie, M. A. Stoner, V. L. Streeter, *SPE of AIME*, Paper No. SPE 2966.

094-08200-350-54

EARTHQUAKE INDUCED TRANSIENT PORE PRESSURES IN EARTH DAMS

(*b*) National Science Foundation.
(*c*) Professor V. L. Streeter, E. B. Wylie.
(*d*) Experimental and theoretical.
(*e*) Study of decay of transient pore pressures in earth dams due to sloshing of the reservoir.

094-08201-410-54

INVESTIGATIONS OF SHORE PROCESSES ON LAKE MICHIGAN

(*b*) Hydrology and Shore Processes sub-project of University of Michigan, Sea Grant Program. Sponsored by National Science Foundation.
(*d*) Field investigation.
(*e*) To study rates of erosion and their causes with particular emphasis of land use practices and protective procedures.

UNIVERSITY OF MICHIGAN, College of Engineering, Department of Engineering Mechanics, Ann Arbor, Mich. 48104. Dr. J. W. Daily, Department Chairman.

095-06171-250-20

DRAG REDUCTION

(*b*) Office of Naval Research.
(*c*) Professor W. P. Graebel.
(*d*) Theoretical and experimental basic research.
(*e*) An investigation of the effect of non-Newtonian fluid properties on drag reduction.
(*g*) Theoretical and experimental solutions have been obtained to a number of problems which are discussed in the publications below.
(*h*) **On Determination of the Characteristic Equations for the Stability of Parallel Flow,** W. P. Graebel, *J. Fluid Mech.* **24**, 3, pp. 497-508, 1966.

Technical report (ORA), **Laser Anemometer Measurements of Turbulence in Non-Newtonian Pipe Flow,** W. P. Graebel, J.-S. Chung, *Phys. Fluids*, Apr. 1972.
Applications of Invariant Imbedding Techniques to Flow Instability Problems, W. P. Graebel, M. L. Curl, to appear in *SIAM J. of Appl. Math.*, 1972.

095-07447-000-54

STABILITY OF UNSTEADY FLOWS

(*b*) National Science Foundation.
(*c*) Professor C.-S. Yih.
(*d*) Theoretical.
(*e*) Investigation of stability of time-dependent flows and temperature fields.
(*g*) Solutions obtained are given in the publications listed below.
(*h*) **Stability of Unsteady Flows or Configurations, Part 2. Instability of a Horizontal Liquid Layer on an Oscillating Plane,** C.-S. Yih, *J. Fluid Mech.* **31**, pp. 737-751, 1968.
Instability of Time-Period Flows of Stratified Fluids, C.-H. Li, *Phys. Fluids* **13**, pp. 1121-1134, 1970.
Stability of Unsteady Flows or Configurations, Part 2, Convective Instability, C.-S. Yih, C.-H. Li, to be published in *J. Fluid Mech.*, 1972.

095-07448-020-54

TURBULENCE IN A STRATIFIED FLUID

(*b*) National Science Foundation.
(*c*) Professor Walter Debler.
(*d*) Experimental.
(*e*) Investigation of effects of stratification on turbulence inception and decay.
(*g*) Grid generated turbulence decay results obtained. Turbulent wake breakdown behind a cylinder has been examined.

095-08604-060-20

STRATIFIED FLOWS AND INTERNAL WAVES

(*b*) Office of Naval Research.
(*c*) Professor C.-S. Yih.
(*d*) Theoretical.
(*e*) Investigation of the mechanics of stratified fluids in several areas.
(*g*) Solutions are given in the publications listed below.
(*h*) **Waves in Flowing Water,** C.-S. Yih, *J. Fluid Mech.* **51**, pp. 209-220, 1972.
Waves In, and Stability Of, Stratified Flows, *Proc. 8th Symp. Naval Hydrodynamics*, Aug. 1970.
Stratified Flows, *Cornell Lectures*, Cornell Univ. Press.

095-08605-060-00

THREE-DIMENSIONAL EFFECTS IN A STRATIFIED FLUID

(*c*) Professor Walter Debler.
(*d*) Experimental.
(*e*) Extent of blocking and selective withdrawal in three-dimensional geometries.

UNIVERSITY OF MICHIGAN, Cavitation and Multiphase Flow Laboratory, Department of Mechanical Engineering, Ann Arbor, Mich. 48105. Frederick G. Hammitt, Professor-in-Charge (reports on all projects available by writing to laboratory).

096-06144-230-54

ASYMMETRIC BUBBLE COLLAPSE

(*b*) National Science Foundation.
(*c*) Professor F. G. Hammitt.
(*d*) Theoretical and experimental; basic research for thesis.
(*e*) Study of the asymmetric collapse of vapor (and gas) bubbles in fluid stream.

096-06147-230-54

BUBBLE NUCLEATION, GROWTH AND COLLAPSE PHENOMENA

(*b*) National Science Foundation.
(*c*) Professor F. G. Hammitt.
(*d*) Theoretical and experimental; basic research for thesis.
(*e*) Study of the details of the growth and collapse of vapor and gas bubbles in liquids.

096-08123-230-70

CAVITATION AND DROPLET IMPACT EROSION TESTING (Various Small Projects)

(*b*) Birdsboro Corporation, B. F. Goodrich, Westinghouse Electric, General Electric, Chandler Evans.
(*c*) Professor F. G. Hammitt.
(*d*) Experimental, applied research.
(*e*) Determination of the relative resistances of metals and alloys to cavitation and impact erosion under different conditions of temperature and pressure.
(*f*) Some complete, some continuing.

UNIVERSITY OF MICHIGAN, College of Engineering, Department of Meteorology and Oceanography, Ann Arbor, Mich. 48104. Edward S. Epstein, Department Chairman.

097-07482-460-20

SEA SPRAY AND WHITECAPPING

(*b*) Office of Naval Research.
(*c*) Dr. Edward C. Monahan.
(*d*) Experimental with field investigations; basic research.
(*e*) Investigate how fractional whitecap coverage (and sea spray production) varies with wind speed, atmospheric stability, water temperature and salinity, and fetch. Photographic observations are made from research vessels and platforms, and from "ships of opportunity."
(*f*) Great Lakes, oceanic, and laboratory simulation studies completed.
(*g*) Distinctions between fresh and salt water whitecaps determined. Effects of atmospheric thermal stability and fetch now apparent.
(*h*) **Oceanic Whitecaps,** E. C. Monahan, *J. Phys. Oceanog.* **1**, 2, pp. 139-144, Apr. 1971.

097-07483-460-20

AN INVESTIGATION OF THE STRUCTURE OF TURBULENCE AND OF THE TURBULENT FLUXES OF MOMENTUM AND HEAT OVER WATER WAVES

(*b*) Office of Naval Research.
(*c*) Professor Donald J. Portman.
(*d*) Field investigation of some basic questions, part of which is for a Doctoral thesis.
(*e*) Hot-wire and hot-film anemometers, fast response resistance wire thermometers and staff wave gages were used to measure simultaneously u′, v′, w′, T′ (at two heights, 1 to 8 meters above waves) and wave heights in both Lake Michigan and the Atlantic Ocean (Project BOMEX). Influences of waves on the air flow and the fluxes of momentum and sensible heat over them is determined through spectral and cross-spectral analysis.
(*f*) Data processing, analysis and interpretation.
(*g*) Initial results reflect features of the Miles mechanism with enhanced momentum flux at dominant wave frequency. Wave influence in the form of organized air motion is evident up to 6 meters above mean water level. Streamlines of the air motion at the dominant wave frequency show maxima in horizontal velocity over wave nodes, a phase shift with height, distortion and vertical translation, and are compatible with a general pressure greatest over troughs and least over crests.

(*h*) **Turbulence Measurements Made From FLIP in BOMEX,** D. J. Portman, K. L. Davidson, M. A. Walter, *ORA Rept. 08849-3-P*, 40 pp., 1970 (available from NTIS as AD 713860).
An Investigation of the Influence of Water Waves on the Adjacent Airflow, K. L. Davidson, *ORA Report 08849-2-T*, 259 pp., 1970 (available from NTIS as AD 713694).

097-08124-440-44

WATER CIRCULATION AND LOCAL METEOROLOGY

(*b*) Sea Grant Program, Dept. of Commerce.
(*c*) Dr. Edward C. Monahan.
(*d*) Field investigation, basic and applied research, several Doctoral dissertations included.
(*e*) To gain a comprehensive understanding of water circulation in Grand Traverse Bay of Lake Michigan (by measuring currents, periodic and aperiodic, in the Bay) and of mechanisms (e.g., wind stress) by which it is governed.
(*g*) Specific oscillatory modes detected.
(*h*) **Surface Meteorological and Oceanographic Platform,** G. C. Goldman, *U. Mich. Sea Grant Tech. Report 14*, 28 p., Aug. 1971.
Current Meter Observations of the Circulation in Grand Traverse Bay of Lake Michigan; Mooring Methods and Initial Results, R. G. Johnson, E. C. Monahan, *U. Mich. Sea Grant Tech. Report 18*, 58 p., Nov. 1971.

UNIVERSITY OF MICHIGAN, College of Engineering, Department of Naval Architecture and Marine Engineering, Ship Hydrodynamics Laboratory, Ann Arbor, Mich. 48104. R. B. Couch, Laboratory Director.

098-08125-520-22

AN INTEGRATED APPROACH TO THE DETERMINATION OF PROPELLER GENERATED VIBRATORY FORCE ACTING ON A SHIP HULL

(*b*) General Hydromechanics Research Program, Naval Ship Systems Command.
(*c*) William S. Vorus, Newport News Shipbuilding and Dry Dock Co., Newport News, Va.
(*d*) Theoretical; design; applied research; Doctoral thesis.
(*e*) An ideal fluid boundary value problem is formulated and solved using a special application of Green's theorem to determine the vibratory pressure force on a ship hull.
(*f*) Work completed.
(*h*) **An Integrated Approach to the Determination of Propeller Generated Vibratory Force Acting on a Ship Hull,** W. S. Vorus, *Dept. of Naval Arch and Mar. Eng. Rept. 072*, Apr. 1971.

098-08126-520-48

DAMAGED STABILITY OF SHIPS

(*b*) U.S. Coast Guard.
(*d*) Experimental.
(*e*) A family of boxlike vessels of varying beam was tested in irregular beam seas to determine the stability required for survival.
(*f*) Work completed.
(*g*) Metacentric height required for survival was shown to be beam dependent.
(*h*) **Damaged Stability Model Tests of a Series of Boxlike Hull Forms,** B. J. Young, *Ship Hydrodyn. Lab. Rept. 010112*, Nov. 1971.

098-08127-520-22

A RATIONAL STRIP THEORY FOR SHIP MOTIONS

(*b*) General Hydromechanics Research Program, Naval Ship Systems Command.
(*c*) Odd Faltinsen, Det Norske Veritas, Oslo, Norway.
(*d*) Theoretical; Doctoral thesis.
(*e*) Find pressure distribution along a ship due to regular head seas.
(*f*) Work completed.
(*g*) Experimental and theoretical pressure distribution along a prolate spheroid have been compared and agreement is good.
(*h*) **A Rational Strip Theory for Ship Motions: Part II,** O. Faltinsen, *Dept. of Nav. Arch. and Mar. Eng. Rept. 113*, Dec. 1971.

UNIVERSITY OF MICHIGAN—DEARBORN, Division of Engineering, Thermal Engineering Laboratory, Dearborn, Mich. 48128. Professor Tsung y. Na, Laboratory Director.

100-08157-630-00

JET PUMP PERFORMANCE AT ELEVATED TEMPERATURES

(*d*) Basic research; experimental investigation.
(*e*) Search for basic information about the flow characteristics of jet pumps at elevated temperatures.
(*f*) Continued in the direction of incorporating the experimental data in the optimum design procedures developed earlier in the laboratory.
(*g*) The project represents the first extensive experimental work on jet pump performance study at higher temperatures.
(*h*) **Performance of Liquid Jet Pumps at Elevated Temperatures,** *Proc. Symposium of Jet Pumps and Ejectors*, British Hydromech. Res. Assoc., Cranfield, England, Nov. 1972.

100-08158-210-00

TURBULENT CHANNEL FLOW

(*d*) Basic research; theoretical study.
(*e*) Study the various eddy viscosity and conductivity models and formulations in turbulent channel flows, and various numerical methods suitable for such problems.
(*g*) One of the useful results obtained from this study is the development of a new mixing length model which predicts the velocity and temperature distributions and the Nusselt number for fluids with low, medium and high Prandtl numbers ($Pr = .02$ to 15) and fits experimental data very accurately for Reynolds number greater than 10^4.
(*h*) **Analysis of Turbulent Flow in Pipes with Mass Transfer,** to be published in *J. of Basic Engrg., Trans. ASME.*
Heat Transfer in Turbulent Pipe Flow Based on a New Mixing Length Model, submitted for publication.

UNIVERSITY OF MINNESOTA, Department of Aerospace Engineering and Mechanics, Minneapolis, Minn. 55455. Professor P. R. Sethna, Department Head.

101-07488-000-54

HYDRODYNAMIC STABILITY

(*b*) National Science Foundation.
(*c*) Professor Daniel D. Joseph.
(*d*) Theoretical; basic research; M.S., Ph.D. theses.
(*e*) Theoretical research on the stability of a broad class of fluid motions.
(*g*) The implications of energy analysis for the stability of classical motions (Couette and Poiseuille flows in annuli, pipes, channels, etc., and variations on the Benard problem) are emphasized. A global theory of stability is sought in which linear theory, energy theory and the theory of branching solutions of the Navier-Stokes equations play unique and complementary roles. Also developed are aspects of near-linear perturbation theories.
(*h*) **Existence of Convective Solutions of the Generalized Benard Problem Which are Analytic in Their Norm,** D. D. Joseph, P. Fife. Accepted for publication in the *Archive for Rational Mechanics and Analysis.*

Nonlinear Diffusion Induced by Nonlinear Sources, D. D. Joseph, E. M. Sparrow. Submitted for publication in *Quarterly of Applied Mathematics*.
Viscous Incompressible Flow Between Concentric Rotating Spheres, Part I: The Basic Flow, D. D. Joseph, B. Munson. Accepted for publication in *J. Fluid Mechanics*.
Viscous Incompressible Flow Between Concentric Rotating Spheres, Part II: Hydrodynamic Stability, D. D. Joseph, B. Munson. Accepted for publication in the *J. Fluid Mechanics*.
A Domain Perturbation Method with Applications to Free Surface Problems, D. D. Joseph, to be submitted to *Arch. Rational Mech. Analysis*.
The Free Surface on a Simple Fluid Between Cylinders Rotating at Different Speeds, D. D. Joseph, R. Fosdick, to be submitted to *Arch. Rational Mech. Analysis*.
Hydrodynamic Stability, D. D. Joseph, to be published in *Advances in Applied Mechanics* **13**, pp. 60-100, 1973.

101-07489-020-20

THEORY OF TURBULENCE

(*b*) Department of the Navy, ONR.
(*c*) Professor T. S. Lundgren.
(*d*) Theoretical; basic research.
(*e*) Approximate equations describing shear turbulence are proposed and solved for specific flow situations.
(*g*) Turbulent pipe and channel flow and turbulent plane Couette flow are studied by means of turbulent model equations first proposed by Prandtl.
(*h*) **Turbulent Pipe and Channel Flow**, T. S. Lundgren, *Phys. Fluids* **14**, 225, 1971.

101-07490-210-54

COUPLED FLOWS IN DUCTS AND POROUS MEDIA

(*b*) National Science Foundation.
(*c*) Gordon S. Beavers, Assoc. Professor.
(*d*) Theoretical and experimental; basic and applied research; M.S., Ph.D. theses.
(*e*) Analytical and experimental research is being performed on a broad class of problems involving flows through and around permeable materials. The experiments include both liquid and gas flows through permeable materials. Flows in channels with non-permeable walls are also under investigation.
(*g*) The following projects are active: (1) Investigation of the slip velocity at a porous wall. (2) Non-Darcy flows through porous materials and packed beds of particles. (3) Laminar-turbulent transition in ducts with permeable and impermeable walls. (4) Compressible flows in permeable materials. (5) The effects of slip velocity on a variety of flow configurations.
Experiments on the Breakdown of Laminar Flow in a Parallel-Plate Channel, G. S. Beavers, E. M. Sparrow, R. A. Magnuson, *Intl. J. Heat and Mass Transfer* **13**, pp. 809-815, 1970.
Experiments on Hydrodynamically Developing Flow in Rectangular Ducts of Arbitrary Aspect Ratio, G. S. Beavers, E. M. Sparrow, R. A. Magnuson, *Intl. J. Heat and Mass Transfer* **13**, pp. 689-702, 1970.
Experiments on Coupled Parallel Flows in a Channel and a Bounding Porous Medium, G. S. Beavers, E. M. Sparrow, R. A. Magnuson, *J. Basic Engrg*. **92**, 4, pp. 843-848, 1970.
Channel and Tube Flows with Surface Mass Transfer and Velocity Slip, G. S. Beavers, E. M. Sparrow, L. Y. Hung, *Phys. Fluids* **14**, 7, pp. 1312-1319, July 1971.
Low Reynolds Number Turbulent Flow in Large Aspect Ratio Rectangular Ducts, G. S. Beavers, E. M. Sparrow, J. R. Lloyd, *J. Basic Engrg*. **93**, 2, pp. 296-299.
Flow About a Porous-Surfaced Rotating Disc, G. S. Beavers, E. M. Sparrow, L. Y. Hung, *Intl. J. Heat and Mass Transfer* **14**, pp. 993-996, July 1971.
Effect of Velocity Slip on Porous-Walled Squeeze Films, G. S. Beavers, E. M. Sparrow, I. T. Hwang. Accepted for presentation at the *ASME Conf. on Lubrication*, Oct. 1971, and for publication in the *J. Lubrication Tech*., 1972.
Compressible Gas Flow through a Porous Material, G. S. Beavers, E. M. Sparrow, *Intl. J. Heat and Mass Transfer* **14**, 11, pp. 1855-1857, Nov. 1971.
Incompressible Turbulent Flow in a Permeable-Walled Duct, G. S. Beavers, E. M. Sparrow, V. K. Jonsson, R. G. Owen. Accepted for publication in the *J. Basic Engrg*., *1972*.

101-07491-050-00

VORTEX DEVELOPMENT IN JETS

(*c*) Gordon S. Beavers, Assoc. Professor.
(*d*) Theoretical and experimental; basic and applied research; Ph.D. thesis.
(*e*) The growth of symmetric and alternating vortex sheets in jets is studied for several jet configurations.
(*g*) The growth of vortices in the vortex sheets bounding jets emerging from sharp-edged two-dimensional slits and circular orifices have been studied for jet Reynolds numbers between about 500 and 3000. The two-dimensional jet produces a symmetric pattern of vortex pairs with a Strouhal number of 0.43. Vortex rings are formed in the circular jet with a Strouhal number of 0.63. Computer experiments show that a growing pair of vortices in two parallel vortex sheets produces a symmetric pattern of vortices upstream from the original disturbance. When two plane jets coalesce behind a flat plate, symmetric vortex sheets, similar to those produced in an undeveloped jet, or alternating sheets, similar to those produced in a wake, may be observed.
(*h*) **Vortex Growth in Jets**, G. S. Beavers, T. A. Wilson, *J. Fluid Mech*. **44**, 1, pp. 97-112, 1970.
Vortex Growth in Two-Dimensional Coalescing Jets, G. S. Beavers, A. O. St. Hilaire, T. A. Wilson, to be published in *Trans. ASME*, *J. Basic Engrg*., 1972.

UNIVERSITY OF MINNESOTA, Department of Agricultural Engineering, St. Paul, Minn. 55101. Dr. L. L. Boyd, Department Head.

102-05467-810-00

HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS

(*c*) Professor Curtis L. Larson.
(*d*) Theoretical and experimental; basic and applied.
(*e*) Mathematical modeling techniques are being used to develop better methods for predicting watershed runoff.
(*g*) A simple model for representing infiltraion into a uniform soil as a function of measurable soil characteristics has been developed. Two studies of the relationship between rainfall and runoff recurrence intervals have been completed, one by analysis of rainfall and runoff records, the other by use of a stochastic model.
(*h*) **Modeling the Infiltration Component of the Rainfall-Runoff Process**, R. G. Mein, *Bull. 43*, *Water Resour. Res. Center*, Univ of Minn., Sept. 1971.
Relationship of Observed Rainfall and Runoff Recurrence Intervals, C. L. Larson, B. M. Reich, *Proc. 2nd Intl. Symp. on Hydrology*, Ft. Collins, Colo., Sept. 1972 (in preparation).
Hydrologic Effects of Modifying Small Watersheds–Is Prediction by Hydrologic Modeling Possible? C. L. Larson, *Trans. ASAE*, 1972 (submitted for publication).

102-08159-810-00

PREDICTING PEAK FLOW OF SMALL WATERSHEDS BY USE OF CHANNEL CHARACTERISTICS

(*c*) Professor Curtis L. Larson.

(*d*) Experimental; applied.
(*e*) Observed runoff rates (for ARS watersheds), channel characteristics and mathematical modeling techniques are being used to develop improved methods of predicting peak flows.
(*f*) Completed (summer of 1972).
(*g*) A detailed channel routing study showed the relative accuracy of various routing methods, from standard storage routing methods to numerical solutions of the unsteady flow equations. Analyses of runoff records led to development of a watershed time parameter which could be evaluated from channel characters and checked against hydrographs, if available. The parameter is useful in predicting peak flows.
(*h*) **Hydrograph Routing in Open Channels,** C. E. Rice, C. L. Larson, *Bull. 52, Water Resour. Res. Center*, Univ. of Minn., 1972 (in press).
Using Channel Characteristics to Predict Watershed Time Parameter and Peak Runoff, C. L. Larson, R. F. Gronwald, *Bull. 53, Water Resour. Res. Center*, Univ. of Minn., 1972 (in preparation).

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UNIVERSITY OF MINNESOTA, St. Anthony Falls Hydraulic Laboratory (see ST. ANTHONY FALLS HYDRAULIC LABORATORY listing)

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UNIVERSITY OF MISSOURI—COLUMBIA, Department of Civil Engineering, Columbia, Mo. 65201. Dr. John J. Cassidy, Department Chairman.

103-07497-130-33

DYNAMIC SEPARATION OF SUSPENDED SOLIDS

(*b*) Office of Water Resources Research.
(*c*) Dr. A. T. Hjelmfelt, Jr.
(*d*) Experimental; basic.
(*e*) A study is being made of the efficiency which can be obtained in separating solids from fluids by passing the mixture through an orifice and selectively sampling the resulting concentration as a function of space.
(*f*) Completed.
(*h*) **Dynamic Separation of Solids,** J.-D. Lee, *M.S. Thesis*, Civil Engrg. Dept., Univ. of Missouri, June 1970.
Dynamic Separation of Suspended Solids, *Proc. Hydrotransport 1, 1st Intl. Conf. on Hydraulic Transport of Solids in Pipes*, Paper 134-33, Coventry, England, British Hydromech. Assoc., 1970.

103-07498-210-00

UNSTEADY PRESSURES IN SWIRLING FLOW

(*d*) Experimental and analytical; basic.
(*e*) A study is being made of the conditions of flow arising in straight tubes after vortex breakdown.
(*h*) **Observations of Unsteady Flow Arising After Vortex Breakdown,** *J. Fluid Mech.*, Mar. 1970.
Unsteady Pressures Arising in Swirling Flow, *Trans. 1970 Symp. on Hydraulic Machinery and Cavitation*, Paper E1, Intl. Assoc. Hydr. Res., Stockholm, Sweden, Aug. 1970.

103-07500-440-60

CIRCULATION IN SHALLOW LAGOONS

(*b*) Missouri Water Pollution Control Board.
(*c*) Dr. Henry Liu.
(*d*) Experimental and analytical; basic.
(*e*) Circulation patterns in shallow lagoons as a result of wind are being studied in a wind tunnel and analytically with a digital computer.
(*f*) Completed.
(*h*) **Wind-Induced Circulation in Shallow Lagoons,** H. Perez, *M.S. Thesis*, Civil Engrg. Dept., Univ. of Missouri, Feb. 1970.

103-08192-860-33

REAERATION OF WATER WITH TURBINE DRAFT-TUBE ASPIRATORS

(*b*) Office of Water Resources Research.
(*d*) Experimental; basic.
(*e*) Air is being injected into flow simulating conditions downstream from a turbine. Dissolved oxygen content is measured before and after air is injected. Efficiency of aeration is being correlated with flow and physical parameters.

103-08193-860-61

OPERATING GUIDELINES FOR MULTIPLE-PURPOSE RESERVOIRS

(*b*) Missouri Water Resources Center.
(*c*) Dr. Allen T. Hjelmfelt, Jr.
(*d*) Analytical, applied.
(*e*) Application of Moran-Gould method of estimating reservoir yield to evaluation of operating guidelines for multiple purpose reservoirs.
(*f*) Completed.
(*h*) **Operating Guidelines for Multiple Purpose Reservoirs, Completion Report,** OWRR Project No. A-036-M0, Agreement No. 14-31-0001-3225.

103-08194-310-61

OPERATION OF A SYSTEM OF FLOOD CONTROL RESERVOIRS

(*b*) Missouri Water Resources Center.
(*c*) Dr. Allen T. Hjelmfelt, Jr.
(*d*) Analytical, applied.
(*e*) Application of linear programming to schedule releases from a parallel system of flood control reservoirs.

103-08195-070-00

SEEPAGE UNDER STRUCTURE ON FOUR SOIL STRATA

(*c*) Dr. Charles Lenau.
(*d*) Analytical; applied.
(*e*) The seepage under a structure resting on stratified soil is studied.
(*f*) Complete.
(*g*) Presented is a solution for the flow under a flat-bottomed structure resting on four horizontal strata of equal thickness. The solution is expressed as an asymptotic expansion in terms of the structure length. Because only the first two terms are determined, the solution is approximate. However, the second term which gives an estimate of the maximum error indicates that the discharge predicted by the solution is accurate for a wide range of conditions.
(*h*) **Seepage Under Structure on Four Soil Strata,** C. W. Lenau, *J. Engrg. Mech. Div., ASCE* **97,** No. 8058, pp. 223-237, Apr. 1971.

103-08196-820-00

DISPERSION FROM A RECHARGE WELL

(*c*) Dr. Charles Lenau.
(*d*) Analytical; applied.
(*e*) The mixing of waste from a recharge well with natural groundwater is studied.
(*f*) Complete.
(*g*) Presented is a solution for the distribution of waste concentration created by a recharge well. The recharge well is situated in a confined aquifer through which there is a natural uniform flow. It is assumed that the well fully penetrates the aquifer, that the flow is steady and the aquifer medium is homogenous and isotropic. It is also assumed that the recharge waste has the same density and viscosity as the natural groundwater. The solution is expressed in terms of elementary functions and the gamma function.
(*h*) **Dispersion From a Recharge Well,** C. W. Lenau, *J. Engrg. Mech. Div., ASCE* **98,** No. 8813, pp. 2-14, Apr. 1972.

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UNIVERSITY OF MISSOURI—ROLLA, School of Engineering, Department of Chemical Engineering, Rolla, Mo. 65401. Dr. J. L. Zakin, Professor.

104-06404-250-00

EFFECT OF POLYMER STRUCTURE ON DRAG REDUCTION

(*c*) Dr. J. L. Zakin or Dr. G. K. Patterson.
(*d*) Experimental, basic research, M.S. Thesis.
(*e*) The effectiveness of polymer additives in causing drag reduction is being studied in terms of molecular weight, molecular conformation, molecular structure and chain flexibility and concentration as well as mean velocity and diameter of conduit. The objective is to obtain quantitative relationships among these variables.
(*g*) Previous work has shown that molecular conformation in solution, molecular weight, molecular structure and concentration, mean velocity and tube diameter all affect the level of drag reduction and the type of drag reduction observed in polymer solutions. Low values of the molecular rigidity, β, and high values of the entanglement capacity of the polymer chain, m' = M/(M for critical entanglement) have been shown to be important for significant drag reduction.
(*h*) **Prediction of Drag Reduction with a Viscoelastic Model,** G. K. Patterson, J. L. Zakin, *AIChE J.* **14,** 434, 1968.
The Effect of Molecular Charactersitics of Polymers on Drag Reduction, G. C. Liaw, J. L. Zakin, G. K. Patterson, *AIChE J.* **17,** 391, 1971.

104-06405-250-00

TURBULENCE INTENSITIES IN DRAG REDUCING ORGANIC SOLUTIONS

(*c*) Dr. J. L. Zakin or Dr. G. K. Patterson.
(*d*) Experimental; basic research.
(*e*) Details of the turbulence structure of drag reducing and non-drag reducing solutions are being investigated. Turbulence intensities, frequency spectra, integral scales and other turbulence quantities are being compared for drag reducing and non-drag reducing solutions.
(*g*) The results of turbulence measurements in solvents using wedge probes closely check the accepted values for measurements in air. A comparison of wedge, parabolic, cone and cylindrical hot-film probes showed the wedge and parabolic probes gave identical results while cone probes gave slightly low intensities. Cylindrical data were erratic because of eddy shedding. In viscoelastic solutions, high and low values of turbulence intensities are observed depending on the flow velocity. The frequency response of hot-film wedge probes was shown to be flat up to 100 cps so that frequency response of the probe cannot account for these discrepancies. Pressure probe intensity results were found to be inaccurate in viscoelastic fluids except at the center line of a tube.
(*h*) **Response of Hot-Film Wedge Probes in Viscoelastic Fluids,** J. M. Rodriguez, G. K. Patterson, J. L. Zankin, *Proc. Symp. on Turbulence Measurements in Liquids*, Univ. of Missouri–Rolla Continuing Education Series, 1971.
Measurement of Turbulence Intensities with Piezoelectric Probes in Viscoelastic Fluids, J. M. Rodriguez, G. K. Patterson, J. L. Zakin, *J. Hydronautics* **5,** 101, 1971.

104-06407-250-00

DRAG REDUCTION IN ORGANIC SOAP SOLUTIONS

(*c*) Dr. J. L. Zakin or Dr. G. K. Patterson.
(*d*) Experimental; basic research; M.S. thesis.
(*e*) While polymer solution drag reduction has been widely studied, little effort has been given to aluminum disoap additives which may be more effective drag reducers. The effect of soap type and concentration and the influence of flow variables (flow rate and diameter) are being investigated.
(*g*) In aluminum disoap systems in non-polar sovents, diameter and velocity cffects appear to be similar to those in polymer solutions. Soap solutions are sensitive to aging and under certain conditions to mechanical shear. Stabilizing additives can improve the shear resistance and ageing of aluminum disoap solutions.
(*h*) **Effects of Age and Water Content on Drag Reduction in Aluminum Disoap-Hydrocarbon Solutions,** J. L. Zankin, *Nature; Phys. Sci.* **235,** 97, 1972.
Effects of Third Components on Drag Reduction in Aluminum Soap-Hydrocarbon Systems, K. C. Lee, *M.S. Thesis*, Univ. of Missouri–Rolla, 1970.
Drag Reduction in Hydrocarbon-Aluminum Soap Polymer Systems, J. L. Zakin, K. C. Lee, presented *AIChE Symposium on Drag Reduction*, St. Louis, May 1972.

104-06408-120-00

VISCOSITY OF POLYMER SOLUTIONS

(*c*) Dr. J. L. Zakin or Dr. K. G, Mayhan.
(*d*) Experimental; basic research.
(*e*) The effects of polymer concentration, molecular weight, solvent-polymer interactions and polymer structure on viscosity are being investigated.
(*g*) Viscosity concentration data of a number of polymer solutions in "good" solvents fit a single curve when plotted as $\eta sp/C(\eta)$ vs $k'(\eta)$ C up to the region of incipient molecular overlap. Data on a "fair" solvents are being obtained to determine if this relationship holds for these systems also.

104-07501-130-84

SOLID SUSPENSION DRAG REDUCTION

(*b*) Petroleum Research Fund of the American Chemical Society.
(*c*) Dr. J. L. Zakin or Dr. G. K. Patterson.
(*d*) Experimental, basic research, Ph.D. thesis.
(*e*) An investigation of the particle, fluid and flow variables influencing drag reduction in the flow of solid suspensions.

104-07502-120-00

MEASUREMENT OF COMPLEX MODULUS IN DILUTE POLYMER SOLUTIONS

(*c*) Dr. Gary K. Patterson.
(*d*) Experimental, basic research, Ph.D. thesis.
(*e*) An instrument has been developed which is capable of measuring complex shear modulus at audio frequencies in dilute (below interaction) concentrations. Studies of effect of concentration and molecular weight dispersion on complex modulus are planned.
(*h*) **A Measurement of Complex Viscosity with Large Amplitudes,** K.-S. Shen, *Ph.D. Thesis*, Univ. of Missouri–Rolla, 1971.

104-07503-020-00

SEGREGATION INTENSITIES AND REACTION RATES IN A STIRRED TANK REACTOR

(*c*) Dr. Gary K. Patterson.
(*d*) Theoretical, basic research, Ph.D. thesis.
(*e*) Segregation intensity and reaction completion distributions are being calculated for stirred tank flow reactors under various conditions. Results of recent research on mixing are compared in the calculations. Extension from steady state operation to transient conditions is being made.
(*g*) Comparisons with the little experimental data available indicate that the approach gives very realistic results with and without reaction.

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UNIVERSITY OF MISSOURI—ROLLA, School of Engineering, Department of Engineering Mechanics, Rolla, Mo. 65401. Dr. Peter G. Hansen, Chairman.

105-08160-210-00

AN ASYMPTOTIC APPROACH TO THE ANALYSIS OF UNSTEADY DEVELOPING FLOW IN THE ENTRANCE REGION OF A CIRCULAR TUBE

(*c*) Dr. Xavier J. R. Avula.
(*d*) Theoretical investigation; basic research.
(*e*) A rapidly rising and gradually falling pressure gradient is characteristic of a suddenly started flow in the entrance region of a circular tube. By expanding such a pressure gradient function asymptotically it is possible to obtain a closed form solution which is valid for small times. Small time solutions are particularly valid for the problems of rapidly varying fluid flow. In this work momentum–integral equations for the boundary layer development in the entrance region are solved by an asymptotic approach.
(*g*) Expressions for boundary layer thickness, entrance length and velocity profiles are obtained. The technique can be extended to oscillating flow.

MOBIL RESEARCH AND DEVELOPMENT CORPORATION, Field Research Laboratory, P.O. Box 900, Dallas, Tex. 75221. J. S. McNiel, Manager.

106-06391-250-00

TURBULENT FLOW BEHAVIOR OF RHEOLOGICALLY COMPLEX FLUIDS

(*c*) J. G. Savins, Research Associate.
(*d*) Applied research and development.
(*e*) Studies of turbulent flow in aqueous and non-aqueous media containing high molecular weight polymers, micelle-forming materials, and particulates, and exhibiting drag reducing activity. Objectives include understanding of different manifestations of drag reduction phenomena displayed in internal and external flows, and under conditions similar to those encountered in practical engineering applications.
(*g*) Investigation of the drag reduction effect in large diameter pipes is planned.
(*h*) **Drag Reduction,** J. G. Savins, P. S. Virk, Co-editors, *Chem. Engrg. Progress Symp. Series* **67,** 11, 1971, Amer. Inst. Chem. Engrs., N.Y.

106-07511-120-00

COMPLEX FLUID BEHAVIOR

(*c*) J. G. Savins, Research Associate.
(*d*) Applied research and development.
(*e*) Seek new technology relating to rheologically complex flow phenomena. Activities of interest include ducted flows of solutions, slurries, emulsions, foams, and micelle-forming systems, near and non-viscometric flows, development of instrumentation, and improvement of data reduction and analysis techniques.
(*h*) **Non-Newtonian Flow through Porous Media,** J. G. Savins, *Ind. and Engr. Chem.* **61,** 10, pp. 18-47, 1969.
A Comparison of Differential and Integral Descriptions of the Annular Flow of a Power-Law Fluid, G. C. Wallick, J. G. Savins, *J. Soc. Petr. Engr.*, pp. 311-314, Sept. 1969.

MONTANA STATE UNIVERSITY, Department of Agricultural Engineering, Agricultural Experiment Station, Bozeman, Mont. 59715. Professor Charles C. Bowman, Department Head.

107-08161-840-00

SURFACE IRRIGATION HYDRAULICS

(*d*) Research is based on theoretical and field investigations. The theoretical phase has been completed and it is now being applied to field conditions.
(*e*) Theoretical equations were developed for computing the flows required to give efficient application of water by surface flow systems. Curves are now being developed for application as design and management tools. Automation of systems is also included in these studies.
(*h*) **Manning's Equation for Shallow Flow,** C. C. Bowman, *ARS-SCS Proc.*, ARS 41-43, Oct. 1960.
Dimensional Analysis Leading to Efficient Use of Irrigation Water, C. C. Bowman, *ASAE, 1963.*
Vegetative Density Meter, C. C. Bowman, R. Stitt, *Montana Agri. Exp. Station Bull. 611*, 1967.
Semi-Automation of Irrigation, C. C. Bowman, *Intl. Comm. of Irrigation and Drainage*, *Question 24*, Mexico City, 1969.

MONTANA STATE UNIVERSITY, Department of Civil Engineering and Engineering Mechanics, College of Engineering, Bozeman, Mont. 59715. Dr. Glen L. Martin, Department Head.

108-0115W-840-00

DRAINAGE CORRELATION RESEARCH PROJECT

(*e*) See *WRRC* **6,** 2.0985.
(*f*) Project completed August 1970.
(*h*) Final Report May 1971.

108-0116W-800-00

DEVELOPMENT OF A STATE WATER PLANNING MODEL

(*e*) See *WRRC* **7,** 6.0754.
(*f*) Project completed September 1972.

108-0162W-800-00

WATER RESOURCES IN SOURDOUGH AND MIDDLE CREEK WATERSHEDS–A COMPARATIVE STUDY OF QUALITY AND HYDROLOGY

(*e*) See *WRRC* **6,** 5.0875.
(*f*) Project completed June 1971.
(*h*) Final Report April 1972.

108-07513-260-06

PIPELINE TRANSPORT OF WOODCHIP AND WATER MIXTURES

(*b*) U.S. Dept. of Agriculture, Forest Service.
(*c*) Dr. W. A. Hunt.
(*d*) Theoretical and experimental research. Applied research on 8-in. diameter pilot line installation.
(*e*) Studies in progress are investigations of head losses in straight pipes transporting mixtures of woodchips and water; development of a mechanical system for injecting large quantities of woodchips continuously into a pipeline system; corrosion effects of water and woodchip mixtures on steel pipes.
(*g*) Correlations of friction losses in straight pipes with velocity and concentration of woodchips were completed. Test loop and facilities for conducting tests in 2000 feet of 8-in. diameter pipe are under construction.
(*h*) **The Hydraulic Transport of Wood Chips in Pipelines,** J. L. Gow, *Ph.D. Thesis*, Montana State Univ., Bozeman, 1971.

108-08162-800-61

OPERATIONS MODEL FOR MONTANA'S WATER RESOURCES

(*b*) Montana Univ. Joint Water Resources Research Center.
(*c*) Professor T. T. Williams.
(*d*) Experimental, development.
(*e*) A computerized model of selected storage reservoir systems for the optimal use of reservoir contents for irrigation, flood control and recreation purposes.

108-08163-370-47

HYDROLOGIC AND HYDRAULIC RESEARCH FOR CULVERT DESIGN

(*b*) Montana State Highway Dept. and Federal Highway Administration.
(*c*) Dr. E. R. Dodge.
(*d*) Field investigation, theoretical and applied research.
(*e*) A statistical analysis of peak annual floods from 231 Montana watersheds and a regression analysis of the flood frequency data and watershed parameters are used to develop a set of flood peak prediction equations for each of nine geographic regions in Montana. Also a method was developed whereby the Rational Formula can be used to predict peak flows from small, semi-impervious areas. The prediction equations along with the Rational Formula will be used by the Montana State Highway Department to determine design discharges for small hydraulic structures, primarily culverts. The final report will also include a description of the up-to-date procedures for the hydraulic design of culverts.
(*g*) Prediction eqations for the 2-, 5-, 10-, 25-, and 50-year recurrence interval flood peaks have been developed for the nine regions of Montana. Also a computer program has been written to analyze the accuracy of the prediction equations. Work on describing the procedures for the hydraulic design of culverts is nearly complete and the study of the application of the Rational Method is presently underway.

THE CITY COLLEGE OF THE CITY UNIVERSITY OF NEW YORK, School of Engineering, Department of Civil Engineering, Fluid Mechanics Laboratory, New York, N.Y. 10031. Professor Norman C. Jen, Laboratory Director.

110-06185-220-00

CHANGES IN INITIATION OF SEDIMENT MOTION DUE TO FLOW OBSTRUCTION BY PIERS OR SILLS

(*c*) Dr. Walter Rand.
(*d*) Theoretical and experimental; applied research; Master's thesis.
(*e*) If hydrodynamic forces acting on an erodible bed reach values at which sediment motion is impending, a critical or threshold condition is reached. A structure (a pier or sill), if placed in the channel will change flow conditions, and erosion will develop. The principles of sediment transportation mechanics are used, and experiments with sediment beds of impending motion are conducted, to determine the erosion characteristics as functions of the geometry of the structure, and of the degree of obstruction. Using impending motion conditions as a reference, similarity laws for the erosion pattern will be developed.
(*g*) Preliminary experiments with a rectangular channel indicate that the erosion length downstream of sills is a function of the Froude number, provided the impending motion conditions are used as reference.

110-06186-360-00

A FLEXIBLE APPROACH TO THE DESIGN OF STILLING BASINS

(*c*) Dr. Walter Rand.
(*d*) Theoretical, experimental; development, design.
(*e*) Adopting a generalized concept, a spillway-stilling basin complex can be considered as consisting of an entrance structure, a main basin and an after-basin. The present knowledge on flow under gates and over drop structures, spillways, sills, steps, and baffles is applied to development of a design method in which the design of each structural element is determined individually to achieve the best possible solution for a particular set of conditions. The method would be an extension of current design methods for hydraulic jump stilling basins applicable to cases such as very low tail water, intermittent operation, and rocky channels where the current methods do not offer straightforward solutions. Models are used for verification as the design is evolved.
(*g*) The approach has been used to analyze some of the current design methods. The agreements found and the interpretations of the current methods indicate that further progress is possible. These analyses are published in (h).
(*h*) Discussion of **The Hydraulic Design of Stilling Basins,** W. Rand, *ASCE Proc.* **84,** Paper 1616, April 1958.
Discussion of **Straight Drop Spillway Stilling Basin,** *J. Hyd. Div., ASCE* **92,** HY1, Jan. 1966.

110-07055-870-00

WATER POLLUTION–DISPERSION AND TRANSPORT PROCESS ALONG A COAST

(*c*) Professor Norman C. Jen and Dr. F. F. Yeh.
(*d*) Experimental; applied research; for Master's thesis.
(*e*) By simulating an actual condition along a coast, the processes of dispersion and transport of dissolved and/or other particles are considerd to be important for water pollution problems. The waves, winds and current can be introduced separately or combined together. The test tank is 20 ft. by 10 ft. and 2 ft. in depth.
(*f*) The construction has been recently completed. The investigations are in progress.

110-08164-870-00

HOT TURBULENT DISCHARGE INTO UNIFORM OR DENSITY STRATIFIED ENVIRONMENT

(*c*) Professor Norman C. Jen and Andrew H. Wojtkowski.
(*d*) Experimental and theoretical; applied research; Ph.D. thesis.
(*e*) The process of thermal discharges into uniform or density stratified environment is being simulated. The data of temperature, velocity and turbulence intensity distribution are taken for various flow conditions and discharge nozzle locations. Parallel to the experimental research numerical and analytical work is being conducted. Investigation has an immediate application to water thermal pollution problems.

STATE UNIVERSITY OF NEW YORK AT BUFFALO, Department of Chemical Engineering, Buffalo, N.Y. 14214. William N. Gill, Professor and Provost, Faculty of Engineering and Applied Science.

111-06331-000-54

MECHANISMS OF DISPERSION

(*b*) National Science Foundation and Office of Saline Water.
(*d*) Combined theoretical and experimental; basic research.
(*e*) One of the purposes of this investigation is to delineate the fundamental mechanisms of dispersion for well-defined flows in a variety of physical configurations. This information will then be generalized to describe the dispersion processes in porous media. Another purpose of this work is to establish generalized methods of mathematical analysis for the description of multiphase convective diffusion systems.
(*h*) **Dispersion of a Non-Uniform Slug in Time Dependent Flow,** W. N. Gill, R. Sankarasubramanian, *Proc. Roy. Soc.* (*London*) **322A,** 101-117, 1971.

Taylor Diffusion in Laminar Flow in an Eccentric Annulus, R. Sankarasubramanian, W. N. Gill, *Intl. J. Heat Mass Transfer* **14**, 905-919, 1971.
Laminar Dispersion in Jeffrey-Hamel Flows; Part I, Diverging Channels, W. N. Gill, U. Guceri, *Amer. Inst. Chem. Engrg.* **17**, 207-214, 1971.
Mechanisms Affecting Dispersion and Miscible Displacement; Flow Through Porous Media, R. J. Nunge, W. N. Gill, *Amer. Chem. Soc. Publications*, Washington, D.C., 179-196, 1970.
Exact Analysis of Unsteady Convective Diffusion, W. N. Gill, R. Sankarasubramanian, *Proc. Roy. Soc.* **316A**, 341-350, 1970.
Axial Dispersion with Time Variable Flow in Multiphase Systems, W. N. Gill, *AIChE J.* **15**, 745-749, 1969.
Mechanisms Affecting Dispersion and Miscible Displacement, R. J. Nunge, W. N. Gill, *Ind. Eng. Chem.* **61**, 33-49, 1969.
Laminar Dispersion in Diverging Channels and in Concentric Annuli, W. N. Gill, U. Guceri, R. J. Nunge, *Res. and Dev. Prog. Rept. 443*, Office of Saline Water, U.S. Dept. of Interior, 37 pages, June 1969.
Dispersion in Developing Velocity Fields, W. N. Gill, V. Ananthakrishnan, R. J. Nunge, *AIChE J.* **14**, 939-946, 1968.
Laminar Dispersion in Capillaries, Part V, Experiments on Combined Natural and Forced Convection in Vertical Tube, N. S. Reejshinghani, A. J. Barduhn, W. N. Gill, *AIChE J.* **13**, 100-109, 1968.

111-08165-140-54

CONVECTIVE UNSTEADY INTERPHASE HEAT AND MASS TRANSFER

(*b*) National Science Foundation.
(*d*) Combined theoretical and experimental; basic research.
(*e*) Develop and test experimentally a new general unsteady theory of two- and three-dimensional laminar and turbulent interphase transport processes. The results are applicable to a variety of practical applications including reverse osmosis, thin film chromatography, gas absorption systems and heat exchanger operation.
(*h*) **Mass Transfer with Chemical Reaction from Spherical One or Two Component Bubbles or Drops,** E. Ruckenstein, Vi-D Dang, W. N. Gill, *Chem. Eng. Sci.* **26**, 647-668, 1971.
On the Quasi-Steady State Assumption for Mass Transfer to Spherical Binary Bubbles or Drops, Vi-D Dang, E. Ruckenstein, W. N. Gill, *Chem. Engr., Inst. Chem. Engrs. (London)* **241**, CE 248, Sept. 1970.

111-08166-020-54

MIXING PROPERTIES OF THERMAL AND MATERIAL POLLUTION SOURCES

(*b*) National Science Foundation.
(*d*) Combined theoretical and experimental; basic and applied research.
(*e*) The purpose of this work is to develop and test experimentally a new general unsteady theory of two- and three-dimensional laminar and turbulent mixing processes.
(*h*) **Dispersion of Non-Uniformly Distributed Time Variable Continuous Sources in Time-Dependent Flow,** W. N. Gill, R. Sankarasubramanian, *Proc. Roy. Soc. (London)* **327A**, 191-208, 1972.

111-08167-860-32

REVERSE OSMOSIS WATER PURIFICATION STUDIES

(*b*) Office of Saline Water.
(*d*) Combined theoretical and experimental; basic and applied research.
(*e*) Experimental studies are being conducted to test theoretical analyses and improve efficiency of reverse osmosis systems.
(*h*) **Convective Diffusion in Laminar and Turbulent Hyperfiltration (Reverse Osmosis) Systems, Part I, Review of Laminar Systems,** W. N. Gill, L. Derzansky, M. Doshi, *Surface Sci. Series*, John Wiley, E. Matijevic, Ed., 261-322, 1971.
Convective Diffusion in Laminar and Turbulent Hyperfiltration (Reverse Osmosis) Systems, Part II, Review of Turbulent Systems, W. N. Gill, L. Derzansky, M. Doshi, *Surface Sci. Series*, John Wiley, E. Matijevic, Ed., 322-360, 1971.
Combined Free and Forced Convection in Vertical Semipermeable Parallel Plate Ducts, K. Ramanadhan, W. N. Gill, *AIChE J.* **15**, 872-884, 1969.
Mass Transfer in Laminar Hyperfiltration Systems, W. N. Gill, L. J. Derzansky, M. R. Doshi, *Res. and Dev. Rept. 403*, U.S. Dept. of Interior, 88 pp., Feb. 1969.
Simultaneous Development of Velocity and Concentration Profiles in Reverse Osmosis System, S. Srinivasan, C. Tien, W. N. Gill, *Chem. Eng. Science* **22**, 417-433, 1967.
Nonlinear Convective Diffusion–A Hyperfiltration Application, Y. Nakano, C. Tien, W. N. Gill, *AIChE J.* **13**, 1092-1098, 1967.
Boundary Layer Effects in Reverse Osmosis Desalination, W. N. Gill, D. W. Zeh, C. Tien, *Ind. Eng. Chem. Fund.* **5**, 367-370, 1966.
A Study of Reverse Osmosis Systems for Desalination, W. N. Gill, C. Tien, D. W. Zeh, *Intl. J. Heat Mass Transfer* **9**, 907-923, 1966.
The Relaxation of Concentration Polarization in a Reverse Osmosis Desalination System, C. Tien, W. N. Gill, *AIChE J.* **12**, 722-727, 1966.
Reverse Osmosis in Annuli, W. N. Gill, D. W. Zeh, C. Tien, *AIChE J.* **12**, 1141-1146, 1966.
Concentration Polarization in a Reverse Osmosis System, W. N. Gill, C. Tien, *Ind. Eng. Chem. Fund.* **5**, 149-150, 1966.
Concentration Polarization Effects in a Reverse Osmosis System, W. N. Gill, C. Tien, D. W. Zeh, *Ind. Eng. Chem. Fund.* **4**, 433-439, 1965.

STATE UNIVERSITY OF NEW YORK AT BUFFALO, Department of Civil Engineering, Buffalo, N.Y. 14214. Professor Ralph R. Rumer, Department Chairman.

112-08168-270-00

DAMAGE OF THE RED CELLS BY MECHANICAL SHEAR

(*c*) Dr. Hsin-Kang Chang, Asst. Professor.
(*d*) Experimental; basic research; Ph.D. thesis.
(*e*) To find the correlation between red cell damage and mechanical shear. The red cell damage is expressed both in terms of the survival rate in the body and the reduced activity of enzymes found on the red cell membrane. Radioactive Cr^{51} is used to label the cells, and dogs and rats are used.

112-08169-030-54

HYDRODYNAMIC DRAG ON SUBMERGED MAN

(*b*) National Science Foundation Institutional Funds, SUNY Buffalo.
(*d*) Experimental and analytical.
(*e*) Determine the drag on man moving under water. The study will include the effects of proximity to a free surface or a stratification interface, varying garb, and body positions. A circular swimming tank (60 ft. diameter, 8 ft. × 8 ft. section) is available for prototype experiments. Preliminary work will be done in a scale model (1:20) of the circular towing tank and in a wind tunnel.
(*g*) Results to date include data from wind tunnel experiments, design of force measuring sensor, and construction of model towing tank.

112-08170-440-44

DYNAMIC MODEL STUDY OF LAKE ONTARIO

(*b*) Sea Grant Program, NOAA, Dept. of Commerce.
(*d*) Experimental and theoretical; applied research.
(*e*) A vertically-distorted Froude model of Lake Ontario is being operated. The purpose of the investigation is to study the physical behavior of the lake water mass in response to inflows, outflows, and wind stress. The effect of the earth's rotation is incorporated by studying the model lake inside of a rotating laboratory. Stratification will also be simulated.
(*g*) Results to date include measurements of water level response during mass oscillation including the frictional decay of the oscillations.
(*h*) **Modeling Great Lakes Circulations,** R. Rumer, J. Hoopes, Jr., *Proc. M.I.T. Symp. on the Water Environment and Human Needs*, 212-247, Civil Eng. Dept., M.I.T., Oct. 1970.

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STATE UNIVERSITY OF NEW YORK AT BUFFALO, Department of Engineering Science, Buffalo, N.Y. 14214. Dr. Richard P. Shaw, Professor.

113-08171-470-00

HARBOR RESONANCE

(*d*) Theoretical (primary aim of work at SUNY-B); experimental (in conjunction with colleagues at U. of Hawaii); applied research to aid in harbor design.
(*e*) Response of harbors to incident long-period water waves is examined in order to determine effects of harbor geometry, depth, etc., on resonance wavelengths and amplification factors. Present aim is to examine effects of friction, variable depth and interconnected basins. A related experimental project presently carried out at the U. of Hawaii is to develop an acoustic analog to such problems.
(*g*) The effect of entrance channel length has been found to be as significant as the previously known effect of channel width, i.e., the "harbor paradox." An approximate but accurate method for calculating the response of narrow mouthed harbors has been developed.
(*h*) **The Response of Narrow Mouthed Harbors to Tsunamis,** G. F. Carrier, R. P. Shaw, *Tsunamis in the Pacific Ocean*, Ed. W. M. Adams, East-West Center Press, Honolulu, Hawaii, 377-398, 1970.
The Response of Narrow Mouthed Harbors to Periodic Incident Waves, G. F. Carrier, R. P. Shaw, M. Miyata, *J. App. Mech.* **38,** 2, 334-344, 1971.
Forced Long Period Harbor Oscillations, R. P. Shaw, *Topics in Ocean Engineering III*, Chap. 3, Gulf Publishing Co., Houston, Tex., 1972.
Channel Effects in Harbor Resonance, G. F. Carrier, R. P. Shaw, M. Miyata, *J. Eng. Mech., ASCE* **97,** EM6, 1703-1716, 1971.
An Acoustic Model for the Experimental Study of Water Wave Problems, R. P. Shaw, A. Parvulescu, *J. Acous. Soc. Am.* **50,** 6, Pt. 1, 1443-1446, 1971.
Acoustic Harbor Model, D. A. Hart, A. Parvulescu, R. P. Shaw, *Look Lab/Hawaii* **2,** 1, 3-10, 1971.

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STATE UNIVERSITY OF NEW YORK AT BUFFALO, Fluid and Thermal Sciences Laboratory, Buffalo, N.Y. 14207. Professor K. M. Kiser.

114-08172-210-00

AN EXPERIMENTAL DETERMINATION OF VELOCITY PROFILES FOR LAMINAR AND TURBULENT FLOW IN RIGID TUBES

(*d*) Experimental, basic research for M.S. thesis.
(*e*) Determine the form of the velocity profiles when a fluid is made to flow in an oscillatory mode through a rigid pipe at large (mean) Reynolds numbers.
(*g*) Velocity profiles were measured by hot-film anemometry techniques for flows having mean flow Reynolds numbers to 22,000 and oscillatory parameter, $\alpha = R(\omega/\nu)^{1/2}$, to 22. When the velocity profiles for the steady turbulent flow were subtracted from the total flow formed of this steady flow with a superposed oscillatory component of given α, there remained a residue whose shape was characteristic of a laminar purely oscillatory flow of significantly smaller α. This apparent value for α is closely approximated if the kinematic viscosity in the definition of α is replaced by the eddy viscosity of the steady turbulent flow.
(*h*) **M.S. Thesis,** J. A. Klapetzky, available SUNY/B Library.

114-08173-270-84

SEQUENTIAL VELOCITY PROFILE DEVELOPMENT IN THE ASCENDING AND DESCENDING AORTA (See also 115-08176.)

(*b*) Heart Association of Southwestern New York.
(*d*) Experimental, basic research for M.S. thesis.
(*e*) Measure the instantaneous velocity profiles in the aortas of dogs using hot-film anemometry techniques, and to compare these profiles with available theory.
(*g*) In general the measurements confirm the observation that the velocity profiles tend to be flat with the highest rates of shear confined to the region of the wall. There are however significant variations in the details of the flow from one dog to another. The general shapes of the profiles at least during early systole, resemble those of a tube flow started impulsively from rest.
(*h*) **M.S. Thesis,** Edward R. Belmore, available University Library.

114-08174-050-54

AN EXPERIMENTAL STUDY OF OSCILLATING SUBMERGED FREE WATER JETS

(*b*) National Science Foundation.
(*d*) Experimental, basic research for Ph.D. thesis.
(*e*) The object of this work is to measure instantaneous mean velocity profiles in a turbulent jet formed of a steady flow with a superposed oscillatory component. Turbulence intensities and spectra are also measured.
(*f*) Completed.
(*g*) For oscillatory frequencies to 8 hertz the mean flow in the jets follows all the decay laws of the steady jet but the scale factors are altered appreciably. The influence of the oscillatory component is negligible beyond about 15 nozzle diameters even when the amplitude of the oscillation is very large. The turbulence intensities are but slightly increased and the spectra are largely unchanged except at the low wave numbers.
(*h*) **Ph.D. Thesis,** P. S. Srinivasan, available University Library.

114-08175-440-00

SUBSURFACE CIRCULATION IN A WIND DRIVEN, STRATIFIED, ROTATING MODEL OF LAKE ERIE

(*d*) Experimental, basic research.
(*e*) Determine the flow velocitities of the water in a scaled model of Lake Erie. The velocities are determined by dye tracer techniques for different conditions of wind stress and simulated stratification. The subsurface flow is examined using a neutrally buoyant dye.
(*f*) Completed.
(*g*) The velocity and flow directions were determined at a depth corresponding to 6.5 meters in the real lake. By varying the wind velocity over the model it is shown that the lake undergoes several transitions in its general motion. These motions are strongly influenced by the stratification of the lake.
(*h*) **M.S. Theses,** G. Peck and W. Pomerhn, available University Library.

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STATE UNIVERSITY OF NEW YORK AT BUFFALO, Department of Mechanical Engineering, Buffalo, N.Y. 14214. Gerald P. Francis, Associate Professor and Department Chairman.

115-08176-270-80

BLOOD FLOW MEASUREMENT USING HOT-FILM ANEMOMETRY (See also 114-08173.)

(*b*) Heart Association of Southwestern New York.
(*c*) Gerald P. Francis, Assoc. Professor, Dept. of Mech. Engineering; Kenneth M. Kiser, Assoc. Professor of Chemical Engineering.
(*d*) Experimental; applied research.
(*e*) Hot-film measurements of the radial distribution of velocity as a function of time in the ascending and descending aorta of open chest dogs. Purpose is to study circulatory abnormalities.
(*g*) Normal velocity profiles appear as a developing flow. There are significant variations in detail which are related to valve inlet geometry, orientation of the aortic valve plane, variations in aortic curvature and arterial branching.

115-08177-270-80

PRESSURE MEASUREMENT WITH FLUID-FILLED CATHETER SYSTEMS

(*b*) United Health Foundation of Western New York; Heart Association of Southwestern New York.
(*c*) Robert E. Mates, Professor.
(*d*) Theoretical and experimental; applied research.
(*e*) Fluid-filled catheter systems are routinely used for direct intravascular diagnostic pressure measurements. The frequency response of these systems is not adequate for many clinical measurements. The project, carried out in conjunction with the Department of Medicine, seeks to develop calibration and compensation methods to improve measurement accuracy.
(*g*) Modified methods for flushing catheters to eliminate microscopic gas bubbles have significantly improved frequency response. Calibration and compensation devices suitable for routine clinical use have been developed and are being evaluated.

115-08178-270-80

HEMODYNAMIC EFFECTS OF PROSTHETIC HEART VALVES AND CIRCULATORY ASSIST DEVICES

(*b*) Heart Association of Southwestern New York.
(*d*) Experimental; applied research.
(*e*) *In vivo* and *in vitro* studies of the relative flow characteristics behind various prosthetic heart valves to examine the influence of induced shear and turbulence on both blood and endothelia cells.

115-08179-050-00

TURBULENT JET FLOW OVER A CYLINDER

(*c*) Ji-Wu Yang, Assoc. Professor.
(*d*) Experimental, basic research, M.S. thesis.
(*e*) Two-dimensional turbulent jet flow over a heated cylinder is studied experimentally. The effect of jet Reynold's number and aspect ratio on static pressure distribution, velocity and temperature profiles and the heat transfer rate are investigated under various conditions.

115-08180-210-54

TURBULENT FLOW IN CONVERGING RECTANGULAR DUCTS

(*b*) National Science Foundation.
(*c*) Ji-Wu Yang, Assoc. Professor.
(*d*) Experimental study; basic research for Master's thesis.
(*e*) Study of the effect of flow acceleration on three-dimensional turbulent flow in rectangular ducts. Characteristics of pressure drop and velocity distributions are determined for ducts of various aspect ratio. Laminarization of the turbulent flow due to acceleration is studied.

115-08181-870-00

LABORATORY MODELING OF OIL SPREAD ON WATER

(*c*) J. Gordon Hall, Professor.
(*d*) Experimental; basic research for Master's thesis.
(*e*) The spread of an oil spill on water has been simulated in a laboratory tank apparatus for both one-dimensional and two-dimensional or radial slicks. The experiments were limited to the initial gravity-inertia and gravity-viscous similarity phases of the spread. Purpose was to check previous data for the one-dimensional case and obtain data for the (previously unstudied) two-dimensional or radial case.
(*f*) Completed.
(*g*) The radial spread data obtained are in fairly good agreement with theoretical estimates.

115-08182-270-80

AN IMPROVED PULSATILE FLOW SIMULATOR

(*b*) Heart Foundation of Southwestern New York.
(*c*) Adam C. Bell, Asst. Professor.
(*d*) Applied research and design project.
(*e*) An electro-hydraulically driven pump is used to perturb a constant bias flow so that their sum simulates any tape recorded cardiac flow. The device will be suitable for measurements on prosthetic valves, including wake profiles, efficiency and wear studies; hot-film probe development for aortic velocity profile measurement; peripheral circulation model development; and evaluation of artificial assist devices.
(*g*) Project at initial testing phase.
(*h*) **An Improved Pulsatile Flow Simulator,** A. C. Bell, J. A. Hitt, G. P. Francis, *Proc. 24th ACEMB* **31**, 2, 1971.

115-08183-600-54

JET INTERACTIONS IN THE TURBULENCE AMPLIFIER

(*b*) National Science Foundation.
(*c*) Adam C. Bell, Asst. Professor.
(*d*) An experimental investigation primarily in applied research, the subject of two Master's theses.
(*e*) Very little is understood of the development of velocity profiles and the transition to turbulent flow in axisymmetric laminar jets. A large scale (1-inch diameter) model has been constructed in which submerged laminar jets of greater than 30 diameters length may be studied. Both velocity profiles and turbulence intensity profiles are being obtained in the undisturbed jet and in jets disturbed by a transverse impinging jet. The motivation for this study is an improved understanding of the interaction region of a fluidic NOR gate known variously as a turbulence amplifier or flow mode amplifier.

STATE UNIVERSITY OF NEW YORK AT STONY BROOK, Department of Mechanics, College of Engineering, Stony Brook, Long Island, N.Y. 11790. Professor Richard S. L. Lee, Department Chairman.

116-07519-130-54

BEHAVIOR OF FIREBRANDS IN A TURBULENT SWIRLING NATURAL CONVECTION PLUME ABOVE A FIRE WHIRL

(*b*) National Science Foundation.
(*d*) Experimental and theoretical; basic research.
(*e*) In recent years, the control of forest fires has become a problem of increasing concern and consequently the understanding of the mechanism by which a free burning fire spreads has been the central objective of much directed effort. It is generally accepted that such a fire spreads in ways intimately related to the convective air movements in and above the fire. From knowledge gained in some most recent large-scale free burning fire experiments and observations, ignition of unignited regions of fuel bed away

from the fire by firebrands carried up and thrown out by the turbulent swirling natural convection plume above a fire whirl has been identified as one of the potentially most hazardous and the least understood of the mechanisms by which a free burning fire spreads. The principal investigator's previously completed plume studies readily supply him with the essential elements of the ground work necessary for the investigation of such a challenging and far more complicated problem. The present investigation consists of two major items. One is a combined theoretical and experimental research of the behavior of firebrands in a turbulent swirling gas-firebrand two-phase natural convection plume above a fire whirl and in the surrounding ambient air. The other is a corresponding research in a tornado-like fire whirl caused by the wind shear action of the ambient atmosphere.

(*g*) In the area of the origin of fire whirls, the interaction between ambient wind shear and the natural convection plume has been identified as the controlling mechanism in the instability of the flow field. In the area of the firebrand trajectory studies, the two-phase interaction and the burning characteristics of the firebrand material are found to contribute overwhelmingly to the dynamics of the firebrand.

(*h*) **Migration in a Laminar Suspension Boundary Layer Measured by the Use of a Two-Dimensional Laser-Doppler Anemometer,** *Proc. Intl. Symp. on Two-Phase Systems,* 1971.

116-07520-730-00

A MAN OF HYDRAULICS; HENRI DE PITOT 1695-1771

(*c*) Professor Rene Chevray.
(*d*) History of hydraulics.
(*e*) To present the contribution made by Pitot in the field of hydraulics at the beginning of the 18th century.
(*f*) Completed.
(*g*) Technical biography of H. de Pitot.
(*h*) *J. Hyd. Div., Proc. ASCE* **95,** HY4, July 1969.

116-07521-020-54

TWO-SPECIES CHEMICAL REACTIONS IN TURBULENCE

(*b*) National Science Foundation.
(*c*) Professor Edward E. O'Brien.
(*d*) Theoretical and experimental, basic research.
(*e*) Investigate reaction surfaces and their role in controlling mixing rates for fast and very fast reactions in turbulence.
(*g*) Theoretical investigations concerning the role of spectral evolution and the manifestation of reaction surfaces in terms of fluctuation moments are in process. Experimental measurements of reactions in the mixing wake behind a flat plate have begun.
(*h*) **Turbulent Mixing of Two Rapidly Chemical Species,** E. E. O'Brien, *Phys. Fluids* **14,** pp. 1326-1331, 1971.
Very Rapid Isothermal Two-Species Reactions in Final Period Turbulence, E. E. O'Brien, *Phys. Fluids* **14,** pp. 1804-1806, 1971.
Two-Species Isothermal Reactions in Homogeneous Turbulence, E. E. O'Brien, *Astronautica Acta* **17,** 10 Pages.
Numerical Examination of Two-Species Reaction in Final Period Turbulence, E. E. O'Brien, C. H. Lin, *Phys. Fluids* **15,** 3 pages.

116-07522-020-54

ONE-SPECIES REACTIONS IN HOMOGENEOUS TURBULENCE

(*b*) National Science Foundation.
(*c*) Professor Edward E. O'Brien.
(*d*) Analytical, basic research.
(*e*) Develop closure approximations which satisfy all known invariances, and which accurately mimic exact solutions for stochastically distributed reactants.
(*f*) Completed.
(*g*) Statistical independence of turbulent mixing and reactions for these systems without reaction surfaces yields quantitatively satisfactory predictions.
(*h*) **A Postulate of Statistical Independence for Decaying Reactants in Homogeneous Turbulence,** E. E. O'Brien, *Phys. Fluids* **12,** 10, 1969.
A Closure for Stochastically Distributed Reactants, E. E. O'Brien, R. M. Eng, *Phys. Fluids* **12,** 9, 1969.

116-07523-520-00

SAILING YACHT RESEARCH

(*c*) Professor Walter S. Bradfield.
(*d*) Experimental and field investigation, applied research.
(*e*) Development of methods of predicting and measuring sailing vehicle performance; development of a hydrofoil sailing vehicle; development of a method for full-scale wind load measurement in the field.
(*h*) **Comparative Performance of the Hydrofoil and the Catamaran,** *Proc. 3rd AIAA Symp. Aero/Hydronautics of Sailing* **10,** pp. 159-169, 1971.
Two chapters in *Hydrofoil Sailing,* Grogono and Nigg. Publisher; Kalerghi Publications, London W1, England.

116-07524-010-26

TURBULENCE MEASUREMENTS IN THE WAKE OF A THIN FLAT PLATE

(*b*) Air Force Office of Scientific Research.
(*c*) Professor Rene Chevray.
(*d*) Experimental, basic research.
(*e*) To offer a critical test of the boundary layer calculation techniques since this flow corresponds to the development of a turbulent boundary layer with zero pressure gradient when the wall shear is suddenly removed at the trailing edge.
(*f*) Completed.
(*g*) The turbulent boundary layers on the two sides of the flat plate merge slowly and transform into the wake as the sudden disappearance of the wall shear diffuses outward. In other aspects the wake region behaves as expected. The large scale quasi-periodic motion often associated with wakes of two-dimensional blunt bodies is conspicuously absent.
(*h*) *AIAA J.* **7,** 8, Aug. 1969.

116-07525-700-26

TEMPERATURE COMPENSATED LINEARIZER FOR HOT-WIRE ANEMOMETER

(*b*) AFOSR and ONR.
(*c*) Professors L. S. G. Kovasznay (Johns Hopkins), R. Chevray.
(*d*) Analytical and experimental, basic research.
(*e*) Linearize the output for low velocity hot-wire anemometry.
(*f*) Completed.
(*g*) A detailed analysis of transistor chains used to generate the desired function is presented. The frequency response of the complete circuit proved very satisfactory. Special attention was given to compensation for temperature sensitivity inherent to solid state devices.
(*h*) *Review of Scientific Instruments* **40,** 1, Jan. 1969.

116-07527-420-00

THE FLUX OF HEAT AND MATTER THROUGH PROGRESSIVE WAVES

(*c*) Professor Edward E. O'Brien.
(*d*) Theoretical, basic research.
(*e*) Determine by exact analytic solution the role of waves in producing changes in mean and fluctuating scalar fields near an interface. Both thin liquid layers on solid surfaces and boundary layers on deep water are investigated.
(*f*) Completed.
(*g*) Fluctuation levels are lower by several orders of magnitude than those measured in the sea surface or in the

laboratory. Simple surface wave enhanced mixing cannot therefore be the explanation of observed fluctuations. Waves on vertical liquid layers at moderate Prandtl numbers may play a significant role in heat transfer.

(*h*) **Surface Temperature and Heat Flux Variation at a Wavy Water-Air Interface,** E. E. O'Brien, T. Omholt, *J. Geophys. Res.* **74,** 13, 1968.

The Effects of Progressive Waves on Convective Transfer, T. Omholt, *Ph.D. Thesis*, Dept. of Mechanics, S.U.N.Y. at Stony Brook, Mar. 1970.

NEW YORK UNIVERSITY, Department of Chemical Engineering, School of Engineering and Science, University Heights, New York, N.Y. 10453. Professor John Happel, Department Chairman.

117-06217-130-00

SEDIMENTATION OF TWO PROLATE SPHEROIDS IN CLOSE PROXIMITY

(*d*) Experimental; basic research.
(*e*) Establish fundamental principles of the behavior of suspensions of small particles in slow motion. Material extractions of prolate spheroids are presently being investigated.
(*f*) Inactive.

NEW YORK UNIVERSITY, Courant Institute of Mathematical Sciences, 251 Mercer Street, New York, N.Y. 10012. Professor Cathleen S. Morawetz.

118-06572-000-20

THEORETICAL PROBLEMS IN HYDRODYNAMICS

(*b*) Office of Naval Research, Mechanics Branch.
(*d*) Theoretical research; basic.
(*e*) Research in the field of classical hydrodynamics in incompressible fluids. Special numerical studies and mathematical analysis of wave motion, gravity waves in heavy jets and viscous flows with free surface.

NEW YORK UNIVERSITY, Department of Meteorology and Oceanography, School of Engineering and Science, University Heights, New York, N.Y. 10453. Department Chairman.

120-03120-450-20

RESEARCH ON PROBLEMS IN PHYSICAL OCEANOGRAPHY

(*b*) Geophysics Branch, Office of Naval Research, Dept. of the Navy.
(*c*) Professors Gerhard Neumann, Willard J. Pierson, A. D. Kirwan, E. S. Posmentier.
(*d*) Experimental and theoretical; basic and applied research.
(*e*) Large-scale oceanographic prediction on numerical integration of the primitive hydrodynamic equations with more realistic boundary conditions.
(*g*) Stratification and circulation of the tropical Atlantic Ocean. Air-sea interaction. Evaporation and precipitation. Quantitative explanation of seasonal salinity variations.
(*h*) **Salinity Surface Variations in the Inner Gulf of Guinea and Their Relation to Evaporation, Precipitation and Vertical Mixing,** G. Neumann, *Sci. Rpt., N.Y.U., Dept. of Meteor. and Ocean., GSL TR-70-10*, Aug. 1970.

Calculation of Infrared Flux at the Sea Surface, *Sci. Rpt., N.Y.U., Dept. of Meteor. and Ocean., GSL TR-71-1.*

The Calculation of Solar Radiation Received and Absorbed at the Sea Surface, R. Dischel, *Sci. Rpt., N.Y.U., Dept. of Meteor. and Ocean., GSL TR-71-2.*

An Evaluation of Stokes Velocities and Inertia Currents Generated by Deep-Water Surface Gravity Waves, H. Chin, *Ph.D. Thesis* and *Sci. Rpt., Dept. of Meteor. and Ocean., GSL TR-71-10.*

A Thrust Anemometer for the Measurement of the Turbulent Wind Vector, G. J. McNally, *M.S. Thesis*, and *Sci. Rpt., N.Y.U., Dept. of Meteor. and Ocean., GSL TR-70-1.*

A Structured Fluids Approach to Canopy Flow, M. Silbert, *M.S. Thesis* and *Sci. Rpt. Dept. of Meteor. and Ocean., GSL TR-70-2.*

Sea Surface Wind Stress: Theoretical Calculations Compared With Direct Measurements, M. P. Clancy, *M.S. Thesis*, and *Sci. Rept., N.Y.U., Dept. of Meteor. and Ocean., GSL TR-70-2.*

An Investigation of Instrumentation and Techniques for Observing Turbulence In and Above the Oceanic Bottom Boundary Layer, H. Frey, *Ph.D. Thesis* and *Sci. Rpt., N.Y.U., Dept. of Meteor. and Ocean., GSL TR-70-16.*

120-06767-450-22

RADAR SATELLITE OCEANOGRAPHY AND OCEAN DYNAMICS

(*b*) Naval Research Laboratory and National Aeronautics and Space Administration.
(*c*) Prof. Willard J. Pierson, Jr., Asst. Prof. Vincent Cardone.
(*d*) Experiment and theoretical; basic and applied research.
(*e*) Development of ways to hindcast and forecast waves completed for Northern Hemisphere. Ways to use radar radiometer from space have been developed. Ways to use S193 on Skylab to test these concepts have been documented by means of extrapolation of aircraft and laboratory data to spacecraft altitudes.
(*g*) Aircraft surface truth program well under way. Results of Pacific Hindcasting study are being extended to the whole earth and ways to incorporate spacecraft data in improved analyses of the surface wind field over the oceans are under development.
(*h*) **Objective Analysis of Sea Level Winds and Pressures Derived from Simulated Observations of a Satellite Radar Radiometer and Actual Conventional Data,** L. Druyan, *N.Y.U., Dept. of Meteor. and Ocean., GSL Tr-71-7.*

A Joint Meteorological, Oceanographic, Geodetic and Sensor Evaluation Program for Experiment S193 on Skylab, E. P. McClain, R. K. Moore, W. J. Pierson, M. Talwani, 1971. Proposal submitted to NASA.

Worldwide Oceanic Wind and Wave Predictions Using a Satellite Radar Radiometer, R. K. Moore, W. J. Pierson, *J. Hydronaut.* **5,** 2, 52-60, 1971.

Spectral Wave Forecasts for 8th U.S. Navy Symp. on Military Oceanograpby, W. J. Pierson 1, pp. 394-406, Naval Postgraduate School, Monterey, Calif.

The Integration of Remote Sensing Data Into Global Weather Prediction, Wave Forecasting, and Oceanic Circulation Computer Based Systems, W. J. Pierson, *Hydrology and Oceanography, 3rd Ann. Earth Resources Program Review*, **III.**

Skylab S193 and the Analysis of the Wind Field Over the Ocean, W. J. Pierson, presented at the *Joint NOAA-Navy Conf. on Sea Surface Topography*, and submitted for publication.

Average Return Pulse Form and Bias for S193 Radar Altimeter on Skylab as a Function of Wave Conditions, W. J. Pierson, E. Mehr, 1971, presented at the *3rd Intl. Symp. on Uses of Artificial Satellite for Geodesy.*

Laser Observations of Wave Growth and Foam Density for Fetch Limited 23 m/s Winds, D. B. Ross, V. Cardone, *Hydrology and Oceanography, 3rd Ann. Earth Resources Program Review* **III.**

Oceanic Whitecapping and Its Relation to Wind Speed and Wave Spectrum, D. B. Ross, V. Cardone, 1971, presented at *Conf. on Interaction of the Sea and the Atmosphere.*

The Extrapolation of Laboratory and Aircraft Radar Sea Return Data to Spacecraft Altitudes, W. J. Pierson, R. K. Moore, 1972, *Hydrology and Oceanography, 4th Ann. Earth Resources Program Review* (in press).
Radar Satellite Oceanography and Ocean Dynamics, W. J. Pierson, V. Cardone, 1972.

120-08184-450-50

LANGLEY AAFE RADSCAT

(*b*) Langley Research Center, NASA, Hampton, Va.
(*c*) Professor Willard J. Pierson, Jr.
(*d*) Experimental and theoretical, basic applied research.
(*e*) Development of an improved theory for radar sea return in terms of the wave number spectrum of a wind roughened sea, design of an experimental procedure for the use of an improved airborne radar-radiometer to gatheradditional simultaneous data on radar sea return and passive microwave emission from the sea surface. (In cooperation with R. K. Moore of the Remote Sensing Lab., Univ. of Kansas, Lawrence, Kansas.)
(*g*) New instrument has been built by G.E. and plans to use it are well along. Theories of sea return have been developed and new models of the spectrum of the sea surface have been derived.
(*h*) **A High Frequency Correction to the Kirchoff Approximation, With Application to Rough Surface EM Wave Scattering,** F. C. Jackson, *N.Y.U., Dept. of Meteor. and Ocean., GSL TR-71-8.*
A Curvature-Corrected Kirchoff Formulation for Radar Sea Return From the Near Vertical, *N.Y.U., Dept. of Meteor. and Ocean., GSL TR-72-1* (in press).
Research On the Problem of the Radar Return From a Wind Roughened Sea, W. J. Pierson, F. C. Jackson, R. A. Stacy, E. Mehr, *Advanced Applications Flight Experiments* (*AAFE*), *Principal Investigators' Review*, pp. 83-106.
The Elevation, Slope and Curvature Spectra of a Wind Roughened Sea Surface, W. J. Pierson, R. Stacy, *N.Y.U., Dept. of Meteor. and Ocean., GSL Tech. Report* (in preparation).

NIELSEN ENGINEERING AND RESEARCH, INCORPORATED, 850 Maude Avenue, Mountain View, Calif. 94040. Dr. Jack N. Nielsen, President.

121-08185-400-33

APPLICATION OF TURBULENT BOUNDARY-LAYER THEORY TO DISPERSION IN ESTUARIES

(*b*) Office of Water Resources Research.
(*d*) Theoretical and experimental; applied research.
(*e*) Turbulent boundary-layer theory will be utilized to model velocity profiles and dispersion in two-dimensional estuaries. The predictions of the method are to be compared with available laboratory data and estuary data. The theory is to be generalized to account for three-dimensional effects neglecting vertical density gradients. The three-dimensional theory is to be applied together with a tidal prediction method to a three-dimensional estuary for which data are available.
(*g*) Methods have been developed for predicting the velocity profiles over the tidal cycle of a two-dimensional estuary. The method remains to be programmed. Dispersion theory for a two-dimensional estuary is now being formulated.

NORTH AMERICAN ROCKWELL CORPORATION, ROCKETDYNE DIVISION, Advanced Systems 6633 Canoga Avenue, Canoga Park, Calif. 91304. J. Hiltabiddle, Manager, New Business and Administration, Advanced Programs.

122-07606-540-50

LOW-SPEED INDUCER FOR A ROCKET ENGINE FEED SYSTEM

(*b*) NASA, Lewis Research Center, Cleveland, Ohio.
(*c*) J. A. King.
(*d*) Theoretical; applied research.
(*e*) Conduct an analytical investigation for the use of low-speed inducers in a rocket engine feed system. Analytical low-speed inducer performance data were developed to evaluate the potential of eliminating propellant tank pressurization and avoiding the resonant interaction of oscillations in the feed system with the vehicle structure.
(*f*) Completed.
(*g*) Transient study results defined low-speed fuel inducer requirements for starting with zero suction pressure. Results of a study of LOX feed system oscillations indicated a low-speed inducer can significantly alter feed system-engine structure frequency response characteristics.
(*h*) **Low-Speed Inducers for a Rocket Engine Feed System,** J. A. King, *NASA Cr-72716 and Rocketdyne R-8272*, June 1970.

122-07607-540-50

DESIGN OF INDUCERS FOR TWO-PHASE OPERATION

(*b*) NASA, George C. Marshall Space Flight Center, Huntsville, Ala.
(*c*) J. A. King.
(*d*) Theoretical and experimental; applied research.
(*e*) Establish the design criteria for pump inducers that will have improved pumping characteristics while pumping two-phase hydrogen.
(*f*) Completed.
(*g*) A mathematical model and a digital computer program were developed for the design and evaluation of inducers for pumping two-phase hydrogen. An inducer was designed according to the developed theory and tested on a J-2 fuel pump in liquid hydrogen. The analytical predictions of maximum vapor volume fraction were found to agree very well with experimental results for hydrogen temperatures between 37 and 45 °R. The two-phase hydrogen inducer accepted three times as much vapor (30 percent) as the J-2 fuel inducer (10 percent) at 41 °R.

122-07608-630-00

IMPELLER CLEARANCE EFFECTS

(*b*) NASA, Lewis Research Center, Cleveland, Ohio.
(*c*) R. K. Hoshide.
(*d*) Theoretical and experimental; applied research.
(*e*) Evaluate the effects of centrifugal pump impeller clearances on rocket engine pump performance and cost. The program consists of a literature survey, an analytical model formulation to predict the effects of impeller tip clearance on performance, a clearance and cost analysis, design and fabrication of the test assembly, and testing of a semi-open impeller at various clearances and comparing the actual and analytically predicted changes in pump performances.
(*f*) Completed.
(*g*) A program of analysis, design, fabrication, and testing has been conducted to develop and experimentally verify the effects of impeller blade clearance of centrifugal pumps. The effects of tip clearance on pump efficiency, and the relationship between the head coefficient and torque loss with tip clearance was established. An impeller, representative of typical rocket engine impellers was modified by removing its front shroud to permit variation of its blade clearances. It was tested in water with special instrumentation to provide measurements of blade surface pressures during operation. Pump performance and blade pressure data were obtained from tests at various impeller tip

clearances. The data were then compared with predicted values, and the model formulation was revised as required to improve correlation.

122-08186-540-50

DESIGN OF INDUCERS FOR TWO-PHASE OXYGEN

(*b*) NASA, George C. Marshall Space Flight Center, Huntsville, Ala.
(*c*) J. A. King.
(*d*) Theoretical and experimental; applied research.
(*e*) Establish the design criteria for pump inducers that will have improved pumping characteristics while pumping two-phase oxygen.
(*f*) Completed.
(*g*) A mathematical model and a digital computer program were developed for the design and evaluation of inducers for pumping two-phase oxygen. An inducer that satisfied the developed theory was tested on a J-2S oxidizer pump in liquid oxygen The analytical predictions of maximum vapor volume fraction were found to agree well with experimental results. The pump was able to handle two-phase oxygen over a wide range of inducer incidence angles and up to a vapor content of 37 percent by volume with very little head loss. The pump was still able to produce some head at vapor fractions approaching 60 percent.
(*h*) **Design of Inducers for Two-Phase Oxygen,** J. A. King, *Rocketdyne R-8832*, Jan. 1972.

122-08187-540-50

POGO INSTABILITIES SUPPRESSION EVALUATION

(*b*) NASA, Lewis Research Center, Cleveland, Ohio.
(*c*) J. A. King.
(*d*) Theoretical and experimental; applied research.
(*e*) Conduct analytical and experimental studies to analyze, design and test an active POGO instability suppression system and to experimentally determine the frequency response and dynamic characteristics of a low-speed inducer, high-speed pump system operating in a liquid oxygen feed system.
(*g*) A dynamic (frequency response) analysis was made of a liquid oxygen feed system consisting of a low-speed inducer, a high-speed main pump and a positive displacement pulser utilized for generating pressure oscillations (POGO). Based on the results of the analysis, an active control system for POGO suppression was designed, fabricated and tested. The test results verified that the suppressor was effective in attenuating the generated pressure oscillations over the frequency range from 10 to 30 cycles per second.

122-08188-540-50

SUPERCAVITATING LOX INDUCER

(*b*) NASA, George C. Marshall Space Flight Center, Huntsville, Ala.
(*c*) E. D. Jackson.
(*d*) Theoretical and experimental; applied research.
(*e*) Goals for the configuration were to achieve a pump suction performance as good, or better than that achieved without a supercavitating inducer; and to achieve lower oscillation amplitudes in the low-frequency, self-induced oscillation range.
(*f*) Completed.
(*g*) The supercavitating inducer was designed to act in tandem with the J-2 LOX pump inducer to provide only sufficient head rise to delay cavitation in the main inducer. The inducer was designed, constructed and tested in combination with a J-2 LOX pump in water. Test results demonstrated that the tandem configuration achieved both of its goals.
(*h*) **Supercavitating LOX Inducer,** E. D. Jackson, *Rocketdyne R-8747*, July 1971.

122-08189-590-00

HYDROTOOL INVESTIGATION

(*c*) F. C. Catterfeld.
(*d*) Experimental and field investigation; development.
(*e*) Develop hydrotool and demonstrate its operational feasibility for naval ship applications. Complete the assembly and experimentally evaluate the hydrotool using water as the driving fluid.
(*f*) Completed.
(*g*) A hydrotool was designed, fabricated, and tested successfully using both hydrant and sea water as the driving fluids. The hydrotool was first attached to a fire hose and fire hydrant. Both steel and aluminum plates were cut using both cutting and grinding wheel attachments. Successful seawater tests were also conducted at various supply pressures and flows. Power developed was about 3 HP at 5300 rpm at pressure across the turbine of 110 psi. Total operational time in seawater was 100 hours.
(*h*) **NUC Test of a Seawater Operated Turbine,** S. A. Christie, E. N. Oeland, Jr., H. Dean, *NUC TN621*, Naval Undersea Res. and Dev. Ctr., San Diego, Calif., Oct. 1971.

122-08190-630-22

FULL-SCALE DESIGN AND EXPERIMENTAL MODEL TESTING OF A WATERJET PUMP FOR A 500-TON CAB TESTCRAFT

(*b*) Joint Surface Effect Ships Program Office, Washington, D.C.
(*c*) G. S. Wong.
(*d*) Experimental; applied research.
(*e*) A full-scale design, a scale-model design and test, and an updated development program plan for a waterjet pump for a 500-ton CAB testcraft were completed.
(*f*) Completed.
(*g*) The testing of the scale-model pump included a series of tests during which the effect of various amounts of inlet flow distortion was investigated. Two different pump inlet elbows were used, one plain and one with vanes. Test results showed that the distorted flow passed through the plain (or unvaned) elbow with only slight attenuation (0 to 50 percent). However, even severe distortion was reduced by an order of magnitude when passing through the vaned elbow. Flow distortion was found to have negligible effect on pump head, flow and efficiency performance. Required NPSH at 2 percent head falloff was increased by a maximum of 28 percent at design flow.

NORTH CAROLINA STATE UNIVERSITY AT RALEIGH, Department of Engineering Research, Raleigh, N.C. 27607. Earl G. Droessler, Administrative Dean for Research, N. W. Conner, Assistant Dean.

123-08197-300-44

NUMERICAL SIMULATION OF UNSTEADY FLOWS IN RIVERS AND RESERVOIRS

(*b*) Office of Hydrology, National Weather Service, Dept. of Commerce.
(*c*) Professor Michael Amein.
(*d*) Theoretical and field.
(*e*) Development of operational computer programs for predicting the water flow in rivers and reservoirs. The study is based on the numerical solution of the one-dimensional unsteady flow equations in open channels by the implicit method.
(*f*) Near completion.
(*g*) Computer programs have been prepared for very general conditions, and have been tested under a variety of field conditions.
(*h*) **Implicit Flood Routing in Natural Channels,** M. Amein, C. S. Fang. *J. Hyd. Div., ASCE* **96,** HY12, Dec. 1970, pp. 2481-2500.

Numerical Simulation of Unsteady Flow in Rivers and Reservoirs, M. Amein (in preparation).

123-08198-400-44

DYNAMICS OF FLOW IN ESTUARINE WATERS

(*b*) Office of Sea Grant, NOAA, Dept. of Commerce.
(*c*) Professors Michael Amein, N. E. Huang, C. E. Knowles.
(*d*) Theoretical and experimental.
(*e*) Study of circulation in Pamlico Sound, N.C., flow through tidal inlets and evaluation of water quality in estuaries of North Carolina. The study of circulation is based on the numerical solution of the spatial two-dimensional shallow water equations by an explicit method. Flow through inlets is based on the numerical solution of one-dimensional open channel flow equations including the solution of channel junction problems. Estuarine water quality models are based on the mass balance equations. Field data are compiled and additional data are taken to test the models.
(*g*) Tables of the numerical values of water velocity and direction and water surface elevation in Pamlico Sound and in Masonboro Inlet, N.C., under the action of tides, freshwater flow and wind have been obtained.

123-08199-820-00

INTERFERENCE BETWEEN GRAVITY WELLS

(*b*) Professor Abdel-Aziz I. Kashef.
(*d*) Theoretical.
(*e*) Stress was previously made on the study of group action of artesian wells. Gravity wells are studied by proposing a restricted superposition procedure. Steady as well as transient states of flow are analyzed.
(*f*) Completed.
(*g*) Unified well equations are proposed for use in either artesian or gravity wells, under either the steady or transient states of flow. The procedure is an essential step in studying the well fields management.
(*h*) **Interference between Gravity Wells-Steady State Flow,** A. I. Kashef, presented at *5th Amer. Water Resources Conf.*, San Antonio, Tex., Oct. 1969, publication underway.
Multiple Gravity Wells Under Transient States of Flow, A. I. Kashef, presented at *5th Amer. Water Resources Conf.*, San Antonio, Tex., Oct. 1969, publication underway.

NORTH CAROLINA STATE UNIVERSITY AT RALEIGH, Department of Mechanical and Aerospace Engineering, Raleigh, N.C. 27607. Dr. R. W. Truitt, Department Head.

124-08191-050-14

A STUDY OF TURBULENT JET ATTACHMENT PHENOMENON

(*b*) U.S. Army Research Office, Durham, N.C.
(*c*) Dr. James C. Williams III, Professor.
(*d*) Theoretical basic research.
(*e*) Study is being made of the two-dimensional turbulent jet reattachment phenomenon. The flow field between jet exhaust and reattachment is being studied for the case where a plane wall, parallel to the nozzle axis, exists near a jet issuing from the nozzle. The two-dimensional boundary layer equations, including curvature effects, are employed in the analysis and these equations are solved using the method of weighted residuals.
(*g*) The analysis has been used to study the location of the reattachment point, the wall pressure distribution and velocity profiles for the flow field. The results obtained have been compared with existing experimental data and it is shown that these results are qualitatively correct.
(*h*) **Curvature Effects in the Laminar and Turbulent Freejet Boundary,** J. C. Williams III, E. H. Cheng, K. H. Kim, *AIAA J.* **9**, 4, pp. 733-736.

UNIVERSITY OF NORTH CAROLINA, School of Public Health, Department of Environmental Sciences and Engineering, Chapel Hill, N.C. 27514. Dr. Daniel A. Okun, Department Chairman.

125-0118W-820-00

(*c*) Dr. J. K. Sherwani, Assoc. Professor.
(*e*) For summary, see *Water Resources Research Catalog* **6**, 4.0203.

125-07533-860-36

IMPROVED DRINKING WATER QUALITY THROUGH DUAL SYSTEMS

(*b*) Office of Water Programs, Environmental Protection Agency.
(*d*) Field investigation with applied research and design; Master's theses.
(*e*) Determination of those circumstances in which a dual water supply system, one supplying pure potable water from protected sources, and the other supplying polluted water or reclaimed wastewater, would be feasible. Synthetic as well as real systems are studied for the costs of alternative approaches involved.
(*f*) The project is now being written up.
(*g*) A dual system was found to cost from 20 to 25 percent more than a conventional system in enlarging water supply systems for existing communities. This does not take into account possible reduced costs for additional water resource development nor the benefits from assuring high-quality water supply free of health risk to consumers.
(*h*) **Feasibility of Dual Water Supply Systems,** F. E. McJunkin, D. A. Okun, presented before the *7th Amer. Water Res. Conf.*, Washington, D.C., Oct. 25, 1971.

125-08202-860-61

REGIONAL DEVELOPMENT OF PUBLIC WATER SUPPLY SYSTEMS

(*b*) UNC Water Resources Research Institute.
(*d*) Field investigation including applied research, design, and Doctoral dissertation.
(*e*) To determine how far municipal water systems should be extended to serve fringe areas; to determine when separated public systems should be physically joined; and to develop a method for determining the least-cost solution for allocating regional water resources to meet regional water supply demands. Real situations are studied for the purpose of developing generalized solutions.
(*g*) Charts are presented that permit ready determination of when a community's water supply system should be extended to fringe areas and when separated communities should be joined, based upon varying densities of population, distances, interest rates, variations in elevation, system size, and the like. For regional optimization, a methodology is described that utilizes a computer program to develop the least-cost allocation of resources in a matrix with water sources versus water demand centers.

125-08203-860-56

ENGINEERING MEASURES FOR CONTROL OF SCHISTOSOMIASIS

(*b*) Agency for International Development.
(*c*) Frederick E. McJunkin, Asst. Professor.
(*d*) Field investigation, design.
(*e*) Review of methods for controlling schistosomiasis, a snail-borne disease infecting some 200,000,000 people in tropical countries. The incidence of the disease is often increased dramatically by water resource development, especially irrigation. Particular emphasis is given to design of engineering facilities affecting disease transmission.
(*f*) Completed.
(*h*) **Engineering Measures for Control of Schistosomiasis,** F. E. McJunkin. Report to the Agency for International Development, Washington, D.C., 1970. Available as *ESE Pub. No. 270*, Dept. Environmental Sciences and Engrg., Univ. of N.C., Chapel Hill, N.C. 27514.

125-08204-860-00

PHYSICAL BEHAVIOR OF FLOCCULENT SUSPENSIONS IN UPFLOW

(*c*) James C. Brown, Assoc. Professor.
(*d*) Theoretical, laboratory, applied research.
(*e*) Study of the physical behavior of various types of flocculent suspensions in upflow clarifiers.
(*f*) Completed.
(*g*) A mathematical model was found which can be used to predict the porosity of flocculent suspension at various upflow velocities.
(*h*) **Physical Behavior of Flocculent Suspensions in Upflow,** J. C. Brown, E. La Motta, *J. Sanitary Engrg. Div., Proc. ASCE* **97,** SA2, pp. 209-224, Apr. 1971.

125-08205-860-00

WASTEWATER REUSE IN NORTH CAROLINA

(*d*) Field study for a Master's thesis.
(*e*) Establish places in North Carolina where wastewater reuse for industrial irrigation and water needs other than for drinking would be most appropriate.
(*h*) **New Directions for Wastewater Collection and Disposal,** *J. Water Poll. Control Fed.* **43,** 11, pp. 2171-2180, 1971.

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NORTH DAKOTA STATE UNIVERSITY OF AGRICULTURE AND APPLIED SCIENCE, Agricultural Engineering Department, Fargo, N. Dak. 58102. Professor W. J. Promersberger, Department Chairman.

126-05471-840-73

DITCH LININGS AND UNDERGROUND PIPE FOR IRRIGATION SYSTEMS

(*b*) Joint project with Carrington Irrigation Branch Station.
(*c*) Superintendent H. M. Olson, Carrington Irrigation Branch Station, Carrington, N. Dak.
(*d*) Field investigation, applied research, design, development, for thesis.
(*e*) Placing various lengths of buried conrete, plastic, concrete asbestos and aluminum pipe for conveying irrigation water on the farm. A concrete lined surface ditch was also used. Such factors as cost of installation, stability of pipe, depth of overburden, hydraulic characteristics, joints and fittings, annual maintenance cost, and life of various types of pipe are to be observed.
(*g*) A progress report is available.
(*h*) **Concrete Pipe and Slip-Formed Ditches for Irrigation in a Northern Region,** H. Holmen, H. M. Olson, *Farm Research* **29,** 2, pp. 11-14, Nov.-Dec. 1971, Reprint No. 760.

126-08206-870-00

FEEDYARD RUNOFF

(*c*) Dr. George L. Pratt.
(*d*) Experimental, applied research.
(*e*) Flow rates of runoff from feedlots in North Dakota will be recorded; pollution potential of this runoff will be determined; and design criteria for runoff collection and disposal systems will be established.
(*g*) Project initiated Fall of 1972. Instrumentation is being installed.

126-08207-870-00

ANIMAL WASTE MANAGEMENT WITH POLLUTION CONTROL

(*c*) Dr. George Pratt.
(*d*) Experimental, applied research.
(*e*) Systems of waste disposal from confinement housing for livestock are being evaluated. Manure slurry and liquid-solid separation are included in the work.
(*f*) Gravity flow of liquids from a concrete floor in a shallow pit under a slatted floor for beef cattle is producing a liquid waste with a solids content of 20,000 mg/l. Remaining solids scraped from the floor have a moisture content of 80 percent. Vacuum filtration of untreated fresh liquid manure from beef cattle yields a liquid with a solids content of 50,000 mg/l. Fertility values and feed values of dehydrated manure are being determined.
(*h*) **Microbial Ecology and Infectious Drug Resistance in a Farm Waste Lagoon,** Y. N. Lee, *Master's Thesis*, June 1971, N. Dak. State Univ. Library.
Transfer of Antibiotic Resistance Between Waste Lagoon Isolates and Human Pathogens, M. Bromel, Y. N. Lee, B. Baldwin, *Bacteriol. Proc. 1971*, p. 76, Minneapolis, Minn.
Antibiotic Resistance and Resistance Transfer Between Bacterial Isolates in a Waste Lagoon, M. Bromel, Y. N. Lee, B. Baldwin, *Intl. Symp. on Livestock Wastes*, Apr. 1971, Columbus, Ohio, p. 35. Publ. in Proceedings.
Handling Livestock Waste, G. L. Pratt, D. W. Johnson, M. L. Buchanan, *N.Dak. Farm Res. Bimonthly Bull.*, Mar.-Apr. 1971. Reprint No. 733, **28,** 4. N. Dak. State Univ. Reports on Environmental Quality.

126-08208-840-00

IRRIGATION SCHEDULING OF MECHANIZED SPRINKLER SYSTEMS

(*c*) Dr. E. C. Stegman.
(*d*) Experimental, applied research.
(*e*) Develop and/or evaluate irrigation scheduling techniques for mechanized sprinkler systems. Components of water loss which influence the irrigation efficiencies of mechanized sprinkler systems are also being studied.
(*g*) A computerized irrigation scheduling service for multiple field management of center pivot sprinkler systems on medium textured soils in central North Dakota is being tested. A 40-acre system was scheduled to irrigate four 32-acre tracts. A 75-acre system was scheduled to irrigate two 75-acre tracts in 1971. Components of water loss during irrigation were also measured. Fifteen tests in 1970 indicated that spray losses to the top of plant canopies were averaging 15 percent. Christiansen's uniformity coefficient averaged 70.8 percent. In 1971, crop water use studies were initiated at Oakes, N. Dak. Data were obtained for small grains, corn, alfalfa, potatoes, sugar beets, and soybeans. Crop coefficient curves for computer irrigation scheduling methods are being developed.
(*h*) **Scheduling For Center Pivot Sprinklers,** J. D. Valer, *Thesis for Master's Degree*, available N. Dak. State Univ. Library.

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NORTHERN MICHIGAN UNIVERSITY, School of Arts and Sciences, Department of Geography, Earth Science and Conservation, Marquette, Mich. 49855. Dr. Henry S. Heimonen, Department Head.

127-06053-440-00

DRIFT BOTTLE STUDY OF THE SURFACE CURRENTS OF LAKE SUPERIOR

(*c*) Dr. John D. Hughes, Assoc. Professor.
(*d*) Field investigation; basic research.
(*e*) To determine the surface current pattern of Lake Superior as it exists during each of the four seasons of the year.
(*g*) 617 returns from 4845 drifters released (Dec. 1969). One preliminary qualitative paper published in Michigan Academician, winter 1970.
(*h*) **Drift Bottle Study of the Surface Currents of Lake Superior,** *Michigan Academician* **III,** 4, Spring 1971. Reprints available from above address.

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NORTHWESTERN UNIVERSITY, The Technological Institute, Evanston, Ill. 60201. Dr. David Mintzer, Dean.

128-03799-030-00

FORCES ON SUBMERGED BODIES IN UNSTEADY MOTION

(*c*) Professors W. S. Hamilton, L. F. Mockros, Dept. of Civil Engineering.
(*d*) Theoretical and experimental; basic research; M.S. and Ph.D. theses.
(*e*) Investigation of the forces on solid bodies accelerating along a rectilinear path through incompressible viscous fluids. The investigation includes experiments that will be compared with numerical evaluation of theoretical linear solutions; experiments on the general case of large motions; and a study of the effect of the velocity pattern on added mass.
(*g*) The Stokes linearized equations of motion were used to obtain the drag on spheroids accelerating parallel to their axes of symmetry. Added mass coefficients were calculated, using potential theory, for submerged spheres moving parallel to a constant-pressure plane. Added mass coefficients were measured experimentally for 6-inch spheres accelerating away from a plane rigid boundary and at the instant acceleration began after a period of constant velocity.
(*h*) **The Stokes-Flow Drag on Prolate and Oblate Spheroids During Axial Translatory Accelerations,** R.Y.S. Lai, L. F. Mockros, *J. Fluid Mech.* **52,** pp. 1-15, 1972.
Fluid Force Analysis and Accelerating Sphere Tests, W. S. Hamilton, J. E. Lindell, *J. Hydraul. Div., Proc. ASCE* **97,** pp. 805-817, June 1971.

128-05472-440-00

DYNAMICS OF THE CIRCULATION IN THE GREAT LAKES

(*c*) Assoc. Prof. G. E. Birchfield, Dept. of Engrg. Sciences.
(*d*) Theoretical study; primarily basic research.
(*e*) Develop mathematical models of wind generated motions in large lakes. Use with recent observational studies to construct model of general circulation.
(*h*) **Response of a Circular Model of a Great Lake to a Suddenly Imposed Wind Stress,** G. E. Birchfield, *J. Geo. Res.* **74,** 23, 5547-5554, 1969.

128-05474-270-40

EXTRACORPOREAL CIRCULATION

(*b*) National Institute of General Medical Science.
(*c*) Professor Lyle F. Mockros.
(*d*) Theoretical and experimental; basic and applied research; M.S. thesis; Ph.D. dissertation.
(*e*) Investigation of the geometry and fluid dynamics favorable to the circulation of blood outside the animal body. Purpose is to obtain design criteria for heart-lung machines.
(*g*) Oxygen and carbon dioxide transfer to and from blood, respectively, is being investigated theoretically and experimentally. Investigations include studies of steady and unsteady laminar convection in various flow geometries.
(*h*) **Artificial Lungs,** L. F. Mockros, M. H. Weissman, Chap. 12, *Biomedical Engineering*, ed. by Brown, Jacobs, Stark, F. A. Davis Co., pp. 325-347, 1971.
Blood-Gas Transfer in an Axial Flow Annular Exchanger, H. K. Chang, L. F. Mockros, *AIChE J.* **17,** pp. 397-401, 1971.
Convective Dispersion of Blood Gases in a Curved Channel Exchanger, H. K. Chang, L. F. Mockros, *AIChE J.* **17,** pp. 541-549, 1971.

128-07537-190-20

ROLE OF THERMAL CONVECTION CURRENTS IN FREEZING OF WATER

(*b*) Office of Naval Research.
(*c*) Professor R. S. Tankin, Dept. of Mech. Engineering.
(*d*) Experimental.
(*e*) To find how thermal convection currents shape the ice-water interface and influence sea ice thickness. A Mach-Zehnder interferometer is used to locate isotherms in the liquid, from which the convection pattern can be deduced.
(*g*) The temperature distribution in the sea water agrees with that calculated by Veronis and shows a reversal of temperature gradient. The ice front that forms in under-cooled sea water, where there is a temperature gradient, extends to the 0 °C isotherm.
(*h*) **Effects of Thermal Convection Currents on Formation of Ice,** R. S. Tankin, R. Farhadieh, *Int. J. Heat Mass Transfer* **14,** pp. 953-961, 1971.
Interferometric Study of Freezing of Sea Water, R. Farhadieh, R. S. Tankin, *J. Geophys. Res., AGU* **77,** 9, pp. 1647-57, Mar. 1972.

128-07539-120-00

FLOW OF SLUDGE IN PIPES

(*c*) Professor W. S. Hamilton, Dept. of Civil Engieneering.
(*d*) Applied research for Ph.D. thesis.
(*e*) Some forms of sludge may be classed as non-Newtonian power law fluids. The viscosity decreases as the shearing rate increases. Therefore, the local viscosity in turbulent flow depends upon the local kinetic energy of turbulence. If the turbulent kinetic energy is approximated by using measurements on the flow of air through pipes, the viscous portion of the shear stress in non-Newtonian flow may be estimated from velocity profile measurements in power law fluids. An attempt is being made to find empirical expressions for the remaining portion of the shear stress, i.e., for the Reynolds stress distribution in power law fluids. The results are to be used to predict velocity profiles and friction factors for sludge flowing through pipes.

128-08209-270-40

PRESSURE AND FLOW IN THE SYSTEMIC ARTERIAL SYSTEM

(*b*) National Institute of General Medical Sciences.
(*c*) Professor Lyle F. Mockros.
(*d*) Theoretical and experimental; basic and applied research; Ph.D. dissertation.
(*e*) The arterial system from the heart to the femoral arteries is mathematically modeled. The method of characteristics is used to study the properties of the physiologic and pathologic arterial system. The purpose is to investigate the effectiveness of various diagnostic and therapeutic techniques.
(*g*) Calculations indicate that reflections are the major factor determining the shape and distal amplification of the pressure wave in the arterial tree; although important in attenuating the proximal transmission of reflecting waves, geometric taper is not the major cause of the distal pressure wave amplification; elastic taper and nonlinearity of the wall elasticity are of minor significance in determining the flow and pressure profiles.

128-08210-270-40

FLUID DYNAMICS IN THE UPPER PULMONARY AIRWAYS

(*b*) National Institute of General Medical Sciences.
(*c*) Professor L. F. Mockros.
(*d*) Theoretical and experimental; basic and applied research; Ph.D. dissertation.
(*e*) Fluid dynamical details in the bifurcating manifolds of the upper airways is being investigated experimentally and analytically. Hot-wire measurements are made in plastic models and in rubber reproductions derived from airway casts. The casts also are used to determine airway geometry. Numerical solutions of the Navier-Stokes equations are used to study the flow behavior through a bifurcating channel.
(*g*) Separation does not appear to be common in the lungs, in spite of the many junctions. Transition sections seem to smooth the flow. The major head losses occur at the junctions, however.

(*h*) **Fluid Dynamics in the Upper Pulmonary Airways,** R. M. Schreck, L. F. Mockros, *AIAA Paper No. 70-788*, pp. 1-6, 1970.

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UNIVERSITY OF NOTRE DAME, Department of Aerospace and Mechanical Engineering, Notre Dame, Ind. 46556. Professor K. T. Yang, Department Chairman.

130-07540-020-00

STUDIES OF NUMERICAL MODELS OF TURBULENT FUNCTIONS

(*c*) Professor R. Betchov.
(*d*) Theoretical, basic research.
(*e*) The signal received from a hot-wire anemometer in a turbulent flow has correlations of odd orders, resulting from phase relations. Experiments done elsewhere have revealed simple relations between correlations of order 3, 5 and 7. This study concerns numerical computations based on simple random nonlinear models to determine generality of these odd-order correlations.

130-07541-020-54

EXPERIMENTS ON STRONG TURBULENCE

(*b*) National Science Foundation.
(*c*) Professor R. Betchov.
(*d*) Experimental, basic research.
(*e*) A turbulence box has been built in our laboratory which is capable of generating one cubic meter of strong turbulence in air under conditions that greatly facilitate the measurements by hot-wire or other techniques. Correlations of order two to eight will be measured to determine the existence of simple relations. Measurements will also be made to examine the dynamics of large vortices as well as to study the intermittency of the turbulence and its effect on diffusion. The student will first become familiar with hot-wire anemometry, and then will have the opportunity to work with this unique facility in turbulence research.

130-07542-720-36

DESIGN OF A METEOROLOGICAL WIND TUNNEL FOR ATMOSPHERIC DIFFUSION STUDIES

(*b*) Environmental Protection Agency.
(*c*) Professors V. W. Nee, K. T. Yang.
(*d*) Experimental, basic research.
(*e*) It has been demonstrated that wind profiles in the surface layer near the ground can be successfully simulated in a wind tunnel under specific conditions. A project has been initiated in our laboratory to design and build such a meteorological wind tunnel with capabilities to simulate ground heating, temperature inversion, and ground or elevated diffusion sources, as well as auxiliary instrumentation and sampling devices.

130-07543-000-00

NUMERICAL EXPERIMENTS IN FLUID MECHANICS

(*c*) Assoc. Professor V. P. Goddard.
(*d*) Theoretical, basic research.
(*e*) Recent studies here at the University of Notre Dame concerning numerical integration of the complete Navier-Stokes equations for flow about a circular cylinder have provided a confidence in the numerical technique. This technique is now extended to the case of an oscillating flow over a circular cylinder.

130-07545-060-20

LAMINAR AND TURBULENT FREE CONVECTION IN A DENSITY STRATIFIED ENVIRONMENT

(*b*) Office of Naval Research and University of Notre Dame.
(*c*) Professors J. L. Novotny, K. T. Yang.
(*d*) Theoretical and experimental, basic research.
(*e*) Our environmental tank (30″ dia. and 60″ high) has been fabricated to permit measurements on the effect of density stratification in a fluid environment on laminar and turbulent free convection along surfaces in the heat and mass transfer. Liquid solutions and gas mixtures up to 200 psia can be accommodated. At this time use is made of a four-inch Mach-Zehnder interferometer for mapping the mass diffusion field in the vicinity of a vertical plate.

130-07546-550-20

STUDIES RELATED TO UNDERSEA JET PROPULSION

(*b*) Office of Naval Research.
(*c*) Professors J. L. Novotny, K. T. Yang.
(*d*) Theoretical and experimental, basic research.
(*e*) To design underwater jet propulsion systems, the basic behavior of underwater jets has to be understood. This study is primarily concerned with the experimental investigation of the pressure and temperature fields surrounding a supersonic steam jet discharging into a channel with slowly moving water flow.

130-07547-030-50

SUBSONIC AXISYMMETRIC TURBULENT WAKE

(*b*) NASA.
(*c*) Professor T. J. Mueller.
(*d*) Experimental, basic research.
(*e*) Detailed measurements will be obtained in the subsonic wind tunnels using hot-wire anemometer and pitot probes. Emphasis will be placed on the influence of Reynolds number and on the phenomenon of separation from the model and recompression or wake closure at the downstream end of the wake.

130-07548-550-20

AXISYMMETRIC AND NON-AXISYMMETRIC ALTITUDE COMPENSATING PROPULSIVE NOZZLES

(*b*) NASA.
(*c*) Professor T. J. Mueller.
(*d*) Experimental, applied research.
(*e*) Experimental study of the nozzle flow field and base drag for several space shuttle afterbody configurations are studied. Thrust and base pressure distribution are measured and flow field examined using various optical techniques.

130-08211-250-20

TWO-PHASE TWO-COMPONENT BOUNDARY-LAYER FLOW OVER A FLAT PLATE WITH SUCTION OR BLOWING

(*b*) Office of Naval Research.
(*c*) Assoc. Professor V. W. Nee.
(*d*) Theoretical, basic research.
(*e*) A computer program is developed to study the effort of nonuniform air blowing and suction on a flat plate in liquid flow. The objective is to determine optimum blowing and suction distributions for stable gas films.

130-08212-010-54

A UNIFIED PHENOMENOLOGICAL THEORY FOR LAMINAR-TRANSITION-TURBULENT BOUNDARY LAYER OVER A FLAT PLATE

(*b*) National Science Foundation.
(*c*) Assoc. Professor V. W. Nee, Professor K. T. Yang.
(*d*) Theoretical, basic research.
(*e*) A prior phenomenological differential field theory for turbulent shear flow is now extended to the transition region.

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517-020 O-LT - 74 - 7

UNIVERSITY OF NOTRE DAME, Department of Civil Engineering, Notre Dame, Ind. 46556. Dr. Don A. Linger, Department Chairman.

131-07549-870-36

BIOGEOCHEMICAL MODELING OF EUTROPHIC LAKES

(*b*) Environmental Protection Agency.
(*c*) W. F. Eschelberger, Jr., M. W. Tenney, P. C. Singer and F. H. Verhoff.
(*d*) Theoretical, experimental and field investigation; M.S. and Ph.D. theses.
(*e*) The purpose of this project is the development of a modeling concept of the ecological system in eutrophic lakes such that the dynamics of this system in a changing environment can be accurately predicted and controlled. Computer techniques are utilized in an attempt to develop a lake model which can be used to predict the water quality of a lake in future years as a result of pollution and/or to establish priorities for the selection of methods of external manipulation of eutrophic lakes (e.g., pollution abatement, bottom sealing, dilution with nutrient free water, etc.) which will most significantly enhance lake recovery.
(*g*) A mathematical simulation (time discrete linear model) of the biogeochemical exchanges within a eutrophic lake system has been developed, and its use in the synthesizing of the eutrophication history of a specific test lake, as the result of pollutional inputs, has been demonstrated. Based on this result it is felt that this model closely approximates the biogeochemical processes in the test lake and can be used to predict future water quality change as a result of certain perturbations on the lake system. Current and planned studies are concerned with a non-linear modeling concept for a more realistic description of the internal lake processes involved and hence better predictive capabilities.
(*h*) **Disinfection of Algal Laden Waters,** W. F. Echelberger, Jr., J. L. Pavoni, P. C. Singer, M. W. Tenney, *Proc. Natl. Specialty Conference on Disinfection*, 1971, 563-583, ASCE, N.Y.
Effects of Domestic Pollution Abatement on a Eutrophic Lake, M. W. Tenny, W. F. Echelberger, Jr., T. C. Griffing, *Report on FWQA Demonstration Grant No. WPD-126*, 1970, 56 pages.
Fly Ash Utilization in the Treatment of Polluted Waters, M. W. Tenney, W. F. Echelberger, Jr., *Bureau of Mines Information Circular 8488–Ash Utilization*, 1970, 237-267.

131-07550-250-40

CHEMICAL CONDITIONING OF BIOLOGICAL SLUDGES TO ENHANCE PIPELINE TRANSPORT

(*b*) National Institutes of Health.
(*c*) W. F. Echelberger, Jr., J. E. Lindell.
(*d*) Theoretical, experimental and field investigation; M.S. and Ph.D. theses.
(*e*) The principal objective in this study is to determine if certain chemical additives, such as synthetic organic polyelectrolytes, can be used to enhance the long distance pipeline transport of biological sludges from wastewater treatment processes. The total scope of the study includes theoretical delineation of the fundamental hydraulic mechanisms, laboratory pipeline studies followed by field evaluation of laboratory results.
(*g*) It has been found that certain polyelectrolytes do enhance the pipeline movement of biological sludges and also assist in dewatering these sludges following discharge from the pipe. The enhancement mechanism appears to be a frictional resistance reduction due to the orientation of the polyelectrolyte additives at the sludge-pipeline interior wall interface.
(*h*) **Chemical Conditioning of Biological Sludges to Enhance Pipeline Transport,** R. C. Hansen, *M.S. Thesis*, 1970.
The Removal of Carbonaceous Phosphatic, and Nitrogenous Pollutants by Biological Treatment, M. W. Tenny, W. F. Echelberger, Jr., K. J. Guter, J. B. Carberry, *161st Nat. Mtg. Amer. Chem. Soc.*, Los Angeles, Calif., Mar. 1971.

131-08213-820-33

HYDROGEOLOGIC FACTORS INVOLVED IN PREDICTING THE EFFECTS OF SANITARY LANDFILL OPERATIONS ON GROUNDWATER QUALITY

(*b*) Office of Water Resources Research.
(*c*) P. C. Singer, J. E. Lindell, J. J. Marley, E. M. Winkler.
(*d*) Theoretical, experimental and field investigation.
(*e*) Determine the effects of solid waste disposal by sanitary landfill methods upon groundwater quality and to relate this effect to rainfall infiltration measurements and to the soil and geological characteristics at the disposal site. These relationships will be used to develop a predictive model for groundwater quality as a function of the several pertinent hydrogeologic parameters.
(*g*) It has been found that several water quality parameters including chemical oxygen demand (COD), hardness, alkalinity, conductivity, and ammonia are significantly higher in samples of groundwater collected from the discharge side of the St. Joseph County, Indiana Sanitary Landfill than in samples collected from a control well. Some of these parameters exhibit a consistent relationship to hydrologic activity as expressed by a rainfall antecedent, with peak concentrations lagging peak antecedent by a regular interval. During the winter months when the ground is frozen and infiltration is inhibited the same parameters are significantly lower in concentration than during the summer months following heavy infiltration.
(*h*) **Groundwater Pollution from the St. Joseph County, Indiana Sanitary Landfill: Hydrologic Aspects,** K. S. Stachiw *M.S. Thesis*, 1972.

OAK RIDGE NATIONAL LABORATORY, Post Office Box X, Oak Ridge, Tenn. 37830. Dr. Alvin M. Weinberg, Director.

132-0163W-860-00

INVESTIGATION OF HYDRODYNAMIC ASPECTS OF REVERSE OSMOSIS

(*c*) D. G. Thomas, U.S. Atomic Energy Commission, Oak Ridge National Laboratory, Oak Ridge, Tenn. 37830.
(*e*) See *Water Resources Research Catalog* **6**, 3.0439.

132-08214-860-00

EFFECT OF HYDRODYNAMICS ON FOULING OF REVERSE OSMOSIS MEMBRANES

(*b*) Office of Saline Water, U.S. Dept. of Interior; Environmental Protection Agency.
(*c*) Dr. David G. Thomas, Oak Ridge National Laboratory, P.O. Box Y, Oak Ridge, Tenn. 37830.
(*d*) Experimental and theoretical; applied research.
(*e*) During the past several years a significant fraction of the hydrodynamic studies of the Water Research Program at the Oak Ridge National Laboratory has been devoted to the study of fouling of cellulose acetate membranes, using Tennessee River Water or primary effluent from the Oak Ridge East Sewage Plant as feed. The primary sewage feed typically has a turbidity of 20 to 50 JTU, 40 to 60 ppm inorganic carbon, 60 to 80 ppm organic carbon, 20 to 40 ppm phosphate, and 40 to 50 ppm calcium plus magnesium. Tennessee River water typically has a turbidity of 5 to 10 JTU with occasional values as high as 60 JTU, and is nearly saturated with calcium carbonate.
(*g*) At pressures of 800 psig and below there is substantially no membrane "compaction" beyond that which may occur in the first five minutes after initial pressurization, and that which has been called compaction is really due to membrane fouling because of poor hydrodyanmics, i.e., too low

an axial velocity past the membrane. A threshold velocity occurs which, when exceeded, minimizes the deposition of particulates. The primary factors affecting the value of the threshold velocity are the initial membrane flux and the size of the particulates. Experimental studies indicate that the threshold velocity is proportional to the square root of the initial membrane flux. Theoretical analysis indicates that in the limit of zero product flux or large particle diameter (larger than 20 microns) the threshold velocity is inversely proportional to the one-fourth root of the particle diameter, while, in the limit of very small particle diameter (smaller than 0.5 micron), the threshold velocity is proportional to the one-fourth power of the product flux and inversely proportional to the three-quarters power of the particle diameter. The rate of flux decline is largely determined by the initial membrane flux and the axial velocity, i.e., the flux decline parameter b, $b = -(\Delta \log \text{flux}/\Delta \log \text{time})$ is proportional to the six-tenths power of the initial membrane flux and is inversely proportional to the square root of the axial velocity.

(*h*) **Control of Concentration Polarization and Arrest of Fouling of Cellulose Acetate Hyperfiltration Membranes by High Axial Velocity,** J. D. Sheppard, D. G. Thomas, *Applied Polymer Symposia, No. 13*, ed. by A. F. Turbak, John Wiley and Sons, 1970, pp. 121-138.
Effect of Axial Velocity and Initial Flux on Flux Decline of Cellulose Acetate Membranes in Hyperfiltration of Primary Sewage Effluents, D. G. Thomas, W. R. Mixon, *Ind. Eng. Chem. Process Design Dev.*, in press.
Hydrodynamic Flux Control for Waste Water Application of Hyperfiltration Systems, D. G. Thomas, R. B. Gallaher, J. R. Love, *Final Report to Environmental Protection Agency by Oak Ridge Nat. Lab.*, Jan. 1972, ORNL-CF-72-3-22.
Membrane Fouling: Part IV. Parallel Operation of Four Tubular Hyperfiltration Modules with Feeds of High Fouling Potential, J. D. Sheppard, D. G. Thomas, K. C. Channabasappa, submitted to *Desalination*.
Membrane Fouling: V. The Effect of Product Water Flux on the Fouling of Hyperfiltration Membranes by Particulates, J. D. Sheppard, D. G. Thomas, in preparation.
Effect of High Axial Velocity on Performance of Cellulose Acetate Hyperfiltration Membranes, J. D. Sheppard, D. G. Thomas, *Desalination* **8**, 1-12, 1970.
Increased Polarization Caused by Films Covering Hyperfiltration Membranes, J. D. Sheppard, D. G. Thomas, *AIChE J.* **17**, 910-915, 1971.

132-08215-130-00

MASS TRANSFER BETWEEN SMALL BUBBLES AND LIQUIDS IN COCURRENT TURBULENT PIPELINE FLOW

(*c*) Dr. T. S. Kress, Oak Ridge National Laboratory, P.O. Box Y, Oak Ridge, Tenn. 37830.
(*d*) Theoretical and experimental; applied research for Doctoral dissertation.
(*e*) Studies are being made of small helium bubbles circulating in pipelines with different mixtures of glycerol and water flowing turbulently. Mass-transfer coefficients between the bubbles and the liquids are being established as functions of Reynolds number, Schmidt number, bubble size, pipe size, and gravitational orientation of the flow. Also determined are bubble size distributions, volume fractions, and surface areas. The application is to the Molten Salt Breeder Reactor in which it is proposed to extract the fission product xenon-135 by circulating small helium bubbles with the liquid fuel. By reducing the concentration of this neutron poison, a significant increase in the breeding ratio can be obtained.
(*g*) Turbulent flow mass transfer Sherwood numbers have been correlated with Reynolds number and bubble mean size for five different Schmidt numbers in both horizontal and vertical flows. It was found that vertical flow mass-transfer coefficients are the same as those for horizontal flow only above certain pipe Reynolds numbers where turbulent inertial forces dominate over gravitational forces. These values of Reynolds numbers marking this equivalence were found to be predictable at a particular value of a newly introduced ::turbulence" Froude number. At lower values of this Froude number, vertical flow coefficients approach asymptotes characteristic of the bubbles rising through a quiescent liquid. In horizontal flows, the bubbles eventually stratify making further operation at lower Froude numbers impractical. The influence of Reynolds number (turbulent energy dissipation) on the Sherwood numbers was found to be different than was expected when compared on an equivalent power dissipation basis with data from agitated vessels. This was attributable to greater gravitational influence in the agitated vessels.
(*h*) **Mass Transfer Between Small Bubbles and Liquids in Cocurrent Turbulent Pipeline Flow,** T. S. Kress, *USAEC Rept. ORNL-TM-3718 (Thesis)*, Oak Ridge Natl. Lab., Dec. 1971.
Liquid-Phase Controlled Mass Transfer in Cocurrent Turbulent Pipeline Flow, T. S. Kress, J. J. Keyes, Jr., submitted to *Chem. Engr. Science*.

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER, Department of Agricultural Engineering, Wooster, Ohio 44691. Dr. G. O. Schwab.

133-0119W-840-00

SURFACE AND SUBSURFACE DRAINAGE FOR SLOWLY PERMEABLE SOILS

(*e*) For summary, see *Water Resources Research Catalog* **6**, 2.1172.

133-0164W-870-00

CHEMICAL AND SEDIMENT MOVEMENT FROM AGRICULTURAL LAND INTO LAKE ERIE

(*e*) For summary, see *Water Resources Research Catalog* **6**, 5.1139.

133-0165W-890-00

STABILIZATION OF STEEP LAND SLOPES

(*e*) For summary, see *Water Resources Research Catalog* **6**, 8.0450.

OHIO STATE UNIVERSITY, Department of Agronomy, Columbus, Ohio 43210. Professor George S. Taylor.

134-05176-840-00

SOIL CHARACTERISTICS AND SUBSURFACE DRAINAGE

(*b*) Ohio Agricultural Experiment Station.
(*d*) Experimental investigation, applied research.
(*e*) Numerical analysis solutions of soil moisture flow problems in subsurface drainage are made with digital computers. Steady-state and transient analyses are studied for various parameters of size, depth, and spacing of tile and ditch drains and of soil hydraulic conductivity. Hillside seepage problems are also evaluated. Field evaluations of hydraulic conductivity are made with the aid of lysimeter-type installations. The principal objective is to interrelate the above factors in rational design of subsurface drainage systems.
(*g*) A method for measuring permeability of field soils was evaluated. The Alternating-Direction-Implicit (ADI) method was adapted for numerical analysis solutions of two-dimensional flow problems.
(*h*) **Soil Hydraulic Conductivity Measurement by Field Monoliths,** E, Stibbe, T. J. Thiel, G. S. Taylor, *Soil Sci. Soc. Amer. Proc.* **34**, **pp.** 852-854, 1970.

OHIO STATE UNIVERSITY, Department of Chemical Engineering, Columbus, Ohio 43210. Aldrich Syverson, Department Chairman.

135-07551-010-54

A VISUAL INVESTIGATION OF THE LAMINAR-TURBULENT TRANSITION

(*b*) National Science Foundation.
(*c*) Robert S. Brodkey or Harry C. Hershey.
(*d*) Experimental; basic; Doctoral theses.
(*e*) An experimental study into the basic mechanism of the entire laminar turbulent tranition for both boundary layer and pipe flow, to elucidate clearly the steps that occur in the transition from laminar to turbulent flow and to clarify which, if any, theories apply for the various steps known to exist.
(*g*) Equipment constructed. Photographs completed on transition downstream of various steps, and on conditions favorable to a Taylor-type transition.
(*h*) **A Visual Study of the Wall Region in Turbulent Pipe Flow,** R. S. Brodkey, E. R. Corino, *J. Fluid Mech.* **37,** 1969.

135-07552-020-54

TURBULENT MOTION AND MIXING

(*b*) National Science Foundation.
(*c*) Robert S. Brodkey.
(*d*) Experimental and theoretical; basic; Doctoral thesis.
(*e*) An experimental and theoretical approach to the basic interactions of turbulence and the mixing of a scalar quantity such as mass. Mixing of heat or mass in a turbulent field can in principle be determined from a knowledge of the existing turbulence in the system and the molecular properties of the material being mixed. The object is to accomplish this prediction.
(*f*) Completed, publications being prepared.
(*g*) A number of papers have been published by the investigators of this work. We have been able to accomplish the prediction for pipe flow and are now working on a reactor configuration. Furthermore, we have been successful in extending the analysis to the prediction of the effect on chemical kinetics.
(*h*) **The Scalar Spectra in the Viscous-Convective Subrange,** R. S. Brodkey, J. O. Nye, *J. Fluid Mech.* **29,** 151, 1969. This paper contains references to older publications.

135-07553-250-54

A VISUAL INVESTIGATION OF DRAG REDUCTION AND DRAG REDUCTION IN NONAQUEOUS SOAP SOLUTIONS

(*b*) National Science Foundation.
(*c*) Harry C. Hershey.
(*d*) Experimental; basic.
(*e*) Experimental study into the basic mechanism of drag reduction in pipe flow using high molecular weight polymer or soap solutions and into the laminar and turbulent behavior of soap solutions. Flow in the wall region of a drag reducing fluid is being compared visually to the flow of a pure solvent. The technique involves high speed photography of colloidal-size particles. A parallel investigation is studying the laminar and turbulent behavior of various aluminum soaps in nonaqueous solvents.

135-08216-010-54

VISUAL INVESTIGATION OF THE TURBULENT BOUNDARY LAYER

(*b*) National Science Foundation.
(*c*) Robert S. Brodkey or Harry C. Hershey.
(*d*) Experimental; basic; Doctoral theses.
(*e*) An experimental study into the basic mechanism of boundary layer flow with emphasis on the interaction of the inner and outer regions.
(*g*) The movies and analysis have been completed. The final thesis is being prepared.
(*h*) **A Visual Study of the Wall Region in Turbulent Pipe Flow,** R. S. Brodkey, E. R. Corino, *J. Fluid Mech.* **37,** 1969.

OHIO STATE UNIVERSITY, Water Resources Center, Columbus, Ohio 43210. Professor George S. Taylor.

136-06734-820-33

WELL DRAWDOWN IN UNCONFINED AQUIFERS UNDER NON-STEADY CONDITIONS

(*b*) Office of Water Resources Research, U.S. Dept. of Interior.
(*c*) Prof. George S. Taylor, Dept. of Agronomy, Ohio State University.
(*d*) Experimental investigations; applied research.
(*e*) A numerical analysis study of drawdown around wells in unconfined porous media for transient conditions. The simultaneous flow of water in both the saturated and unsaturated flow regions is evaluated for various pumping rates and boundary conditions. The entire operation is programmed on an IBM 360 computer. Fulfillment of the project objectives will yield computer techniques for handling complicated water flow problems and additional information on inflow into wells.
(*g*) Drawdown in the near vicinity of wells has been evaluated for porous media which differ in permeability and specific yield. The feasibility of utilizing computer operation for rapid analysis of complex flow problems has been demonstrated.
(*h*) **Computer Methods for Transient Analysis of Water-Table Aquifers,** G. S. Taylor, J. N. Luthin, *Water Resources Res.* **5,** Feb. 1969.

OLD DOMINION UNIVERSITY, Institute of Oceanography, Norfolk, Va. 23508. Dr. John C. Ludwick, Institute Director.

137-08217-220-20

SAND WAVES IN THE TIDAL ENTRANCE TO CHESAPEAKE BAY, VIRGINIA

(*b*) Office of Naval Research.
(*d*) Field investigation; basic research; M.S. theses.
(*e*) To elucidate the connection between sand waves and large sand banks in the tidal entrance to Chesapeake Bay, Virginia. In transverse profile the sand waves include symmetrical and asymmetrical-trochoidal types. By successive bathymetric surveys the migration direction and travel rates of the various types are to be determined. Tidal flows are reversing, unequal, and the degree of dominance varies with geographic position relative to banks and channels. Charting of the net current pattern should also shed light on the evolution of the shoals. Bed shear stress deduced from the vertical distribution of current speed is to be used to estimate net bed sediment transport rate over the area.
(*g*) A transect three miles in length bearing sand waves 5-11 ft. in height and 200-800 ft. in wave length was surveyed 21 times in 17 months. Migration rate of asymmetrical waves was 115 to 492 ft/year seaward. Symmetrical-trochoidal waves did not move significantly. Sand wave height changes seasonally. Height is diminished from October to April when surface water waves are frequently 5 ft. or more in height. Height is augumented from May to September, a period when few storms occur. Facing directions of sand waves and presently fragmentary tidal current data indicate the presence of sand circulation cells conjoint with the large tidal sand banks.
(*h*) **Sand Waves in the Tidal Entrance to Chesapeake Bay: Preliminary Observations,** J. C. Ludwick, *Chesapeake Science* **11,** 2, pp. 98-110, 1970.
Sand Waves and Tidal Channels in the Entrance to Chesapeake Bay, J. C. Ludwick, *Virginia J. Science* **21,** 4, pp. 178-184, 1970.
Migration of Tidal Sand Waves in Chesapeake Bay Entrance, J. C. Ludwick, *Old Dominion Univ., Inst. Oceanog. Tech. Rept. 2*, 89 p., 1971.

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PENNSYLVANIA STATE UNIVERSITY, College of Engineering, Department of Aerospace Engineering, University Park, Pa. 16802. Dr. Barnes W. McCormick, Department Head.

138-08218-120-20

COMPUTATION OF VISCOELASTIC FLOW

(*b*) Fluid Dynamics Program, Office of Naval Research (with partial support of Ordnance Research Laboratory).
(*c*) John L. Lumley.
(*d*) Basic research, computational, Master's thesis.
(*e*) Development of a stable computational scheme for the Oldroyd equations; computation of quasi-one dimensional flows.
(*g*) Parallel flow problems successfully solved; work beginning on quasi-one dimensional problems.

138-08219-700-20

EVALUATION OF LASER-DOPPLER VELOCIMETER

(*b*) Fluid Dynamics Program, Office of Naval Research (with partial support of Ordnance Research Laboratory).
(*c*) W. K. George.
(*d*) Experimental, theoretical, basic Doctoral dissertation.
(*e*) Theoretical and experimental investigation of all sources of noise in the laser-Doppler velocimeter.
(*f*) Completed.
(*g*) Absolute theory successfully predicts measured noise within experimental error. Paper describing results has been submitted to *J. Fluid Mechanics.*

138-08220-120-00

STABILITY OF VISCOELASTIC FLOW

(*c*) John L. Lumley, 153 Hammond, University Park, Pa. 16802.
(*d*) Basic research; Doctoral dissertation.
(*e*) Theoretical analysis of stability to small and large disturbances, two- and three-dimensional, of rectilinear and circular Couette flow of Maxwell fluid, Oldroyd fluid, Walters A′ and B′ fluids and second order fluid.
(*f*) Completed.
(*g*) Most fluids investigated indistinguishable in two-dimensional motion. Stability to three-dimensional disturbances bears one-to-one relation to sign of Weissenberg effect determined from free surface elevation; positive effect produces destabilization.

138-08221-010-00

INVESTIGATION OF THE VISCOUS SUBLAYER

(*c*) W. K. George, Ordnance Research Laboratory, P.O. Box 30, State College, Pa. 16801.
(*d*) Experimental, basic research.
(*e*) Extension of the work of Bakewell to measurement of space-time correlations among all components in the viscous sublayer, and extraction of three-dimensional space-time eigenvalue from the correlation measurements.

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PENNSYLVANIA STATE UNIVERSITY, College of Engineering, Department of Civil Engineering, Hydraulics Laboratory, University Park, Pa. 16802. Dr. Joseph R. Reed, Associate Professor.

140-6208-220-05

BEDLOAD FORMULAS

(*b*) Soil and Water Conservation Research Div., U.S. Dept. Agric., Agric. Research Service.
(*c*) Professor Sam Shulits, Civil Engineering Department, Villanova University, Villanova, Pa. 19085.
(*d*) Analytical; applied research.
(*e*) An attempt to resolve the dilemma of the many existing bedload formulas and an inquiry into their limitations and serviceability. Fourteen of the best known and most used formulas were programmed in Fortran IV for the IBM 360, Model 67, and were also plotted with a subroutine to facilitate comparison.
(*f*) Completed.
(*g*) Three of the programmed formulas were selected as representative of the main types of bedload formulas and as affording adequate agreement with the best known and most used formulas. Of the formulas in which bedload is a function of discharge, the Schoklitsch 1934 formula was selected. For those in which the bedload is a function of the tractive force, two formulas emerged as representative, the Straub-DuBoys and the Meyer-Peter and Mueller formulas. These two formulas may be considered valid for effective diameters from 0.3 to 7mm. The Meyer-Peter and Mueller formula could be employed with caution up to 30 mm on the basis of a single series of uniform-grain tests for the larger diameters. The Schoklitsch formula has the advantages of a simple form and the direct production of a rating curve of bedload versus discharge.
(*h*) **Bedload Formulas,** S. Shulits, R. D. Hill, Jr., *Penn. State Univ., Dept. of Civil Engrg., Hydraulics Lab. Bull.*, 192 pp., Dec. 1968 (out of print; reissued by NTIS, U.S. Dept. of Commerce).

140-07567-260-60

VERTICAL TRANSPORT OF COAL BY PIPELINE

(*b*) Pennsylvania Departments of Environmental Resources and Commerce.
(*d*) Analytical; developmental; Master's thesis.
(*e*) Two-phase upward transport is being studied in order to determine its economic advisability for deep mines. The hoisting of coal coupled with the dewatering of a mine offers an attractive combination to analyze. Opinions with regard to feasibility are quite mixed in the literature. It is likely that feasibility is very conditional.

140-08222-870-00

MODEL STUDY OF STORM SEWER EXIT BELOW AN OVERFLOW NAPPE

(*b*) College of Engineering Central Research Fund.
(*c*) Dr. Gert Aron, Asst. Professor.
(*d*) Experimental.
(*e*) A model of an ogee overflow structure is being built and installed in a laboratory flume. A modeled storm sewer outlet emerges under the nappe of the overfall, thus using the characteristically low pressure at this point to increase the hydraulic gradient available in the sewer for full flow storm water conveyance. Experimentation will hopefully lead to the optimal location and angle of the sewer outlet.

140-08223-200-00

UNIFORM FLOW RESISTANCE IN OPEN CHANNELS

(*c*) Dr. J. R. Reed and Dr. Arthur C. Miller, Asst. Professor.
(*d*) Applied research; experimental.
(*e*) Initially, the effect of shape on the Manning equation will be studied in a variable slope plywood flume utilized in an earlier project. A transition connects rectangular and trapezoidal sections of the flume and at any given time the two shapes have identical flows and slopes. Eventually, it is hoped that measured hot film turbulence levels will correlate with some resistance parameter for this flume as well as for rougher ones.

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PENNSYLVANIA STATE UNIVERSITY, Department of Mechanical Engineering, College of Engineering, Univer-

sity Park, Pa. 16802. Professor Donald R. Olson, Department Chairman.

141-08224-090-00

CONFINED SWIRLING FLOW

(*c*) Professor John A. Brighton.
(*d*) Experimental and analytical applied research; Ph.D. thesis.
(*e*) An analytical and experimental study of confined jet mixing with swirl is being carried out. The effects of swirl on mean flow and turbulence quantities is being examined for a swirling outer flow and a non-swirling jet; and a non-swirling outer flow and a swirling jet. The results provide a calculation method which may be used to assess the performance of devices involving swirling flows.
(*g*) Research is in the beginning stages.

141-08225-050-18

CHARACTERISTICS OF HIGH VELOCITY GASEOUS JETS SUBMERGED IN LIQUIDS

(*b*) Advanced Research Projects Agency, Dept. of Defense.
(*c*) Professor Gerald M. Faeth.
(*d*) Theoretical and experimental; M.S. and Ph.D. thesis research.
(*e*) Investigation considers the flow and transport characteristics resulting from the submerged injection of a high velocity gas into a liquid bath. Of particular interest are those cases where the gas stream is converted to a liquid within the bath. This includes the process of simple condensation of a vapor (e.g., steam-water); dissolving a gas into a liquid (e.g., ammonia-water); and the reaction of a gas with a liquid (e.g., oxidizer-liquid metal). The experimental measurements consider the entrainment characteristics of the jet; mean profiles of velocity, density, temperature, etc.; and the spreading and penetration distance of the gas in the liquid phase. The analysis of this process has employed the turbulent entrainment models of homogeneous free jet theory.
(*g*) The bulk of the experimental work, to date, has considered measurements of vapor jets condensing into liquids. The materials tested have included water, ethylene glycol and iso-octane for a variety of injector diameters and configurations, bath temperatures and pressures, and injector flow rates. The data has mostly been confined to conditions where the injector is choked, in order to avoid unstable injector operation in the unchoked regime. A generalized correlation for the penetration length of a jet has been developed using an entrainment model of turbulent mixing theory, coupled with corrections to allow for underexpansion of the jet in the injector. Present effort involves more detailed measurements of the structure of the flow and consideration of systems involving the injection of halogen or halogenated gases into molten alkali metal baths.
(*h*) **Characteristics of a Submerged Steam Jet**, P. J. Kerney, *Ph.D. Thesis*, Penn. State Univ., Dec. 1970, 95 p.
Penetration Characteristics of a Submerged Steam Jet, P. J. Kerney, G. M. Faeth, D. R. Olson, *AIChE J.*, to be published.
Investigation of a Submerged High Velocity Vapor Jet, J. C. Weimer, *M. S. Thesis*, Penn. State Univ., June, 1972, 66 p.

141-08226-700-00

DEVELOPMENT OF LASER-DOPPLER VELOCIMETER

(*c*) Professor Valdimar K. Jonnson.
(*d*) Experimental, development, Master's thesis.
(*e*) The laser-Doppler velocimeter measures the local velocity of fluid flow by detecting the Doppler frequency shift in coherent monochromatic light as produced by a continuous wave gas laser and scattered from small contaminant particles in the fluid. The scattered and unscattered light are heterodyned on a photo pin diode producing an electric signal, which is measured and displayed by a frequency analyser. The spectral distribution of the frequency shift can be used to measure the velocity for laminar flow and the mean and fluctuating components for turbulent flow.

141-08227-020-00

APPLICATION OF A REYNOLDS STRESS MODEL OF TURBULENCE TO DUCT FLOWS AT ARBITRARY PRANDTL NUMBER

(*c*) Professor Valdimar K. Jonsson.
(*d*) Theoretical, basic research, Ph.D. thesis.
(*e*) A turbulence model, consisting of a generalized invariant set of transport equations for the Reynolds stress tensor and the turbulence energy dissipation rates, is applied to the study of steady convective heat transfer of an incompressible fluid flow in ducts. Of particular interest is the accurate prediction of Reynolds stresses, turbulent heat fluxes and heat transfer rates. The applicability of the transport equation is to be demonstrated by comparison of solutions with existing experiments of pipe and duct flow over a wide range of Prandtl number.

141-08228-140-00

COMBINED NATURAL FORCED CONVECTION

(*c*) Professor Frank W. Schmidt.
(*d*) Experimental and numerical solution of Navier-Stokes equation and the energy equation; Ph.D. thesis.
(*e*) Study of combined natural forced convection in a tube. The effect on the velocity and temperature profiles of tube orientation, Grashof number and the temperature distribution on the tube wall are predicted and found experimentally.
(*f*) Temporarily suspended.
(*g*) The influence of gravity on developing forced, laminar flow in a vertical isothermal tube was investigated by means of a numerical analysis and an associated experiment. Numerically predicted velocity profiles and Nusselt numbers for combined forced-free convection with Gr/Re = −30 are compared with their counterparts for pure forced convection, Gr/Re = 0, for air with Re = 500. The analysis was performed for both the uniform irrotational and the fully developed velocity entrance models. Velocity profiles were measured in a vertical-tube apparatus designed to provide an approximately uniform entrance velocity using air as the test fluid. These are compared with numerical predictions based on test conditions.
(*h*) **Developing Flow with Combined Forced-Free Convection in an Isothermal Vertical Tube**, B. Zeldin, F. W. Schmidt, *ASME Paper 71-HT-6*, to be published in *J. Heat Transfer*.

141-08229-140-00

TURBULENT NATURAL CONVECTION

(*c*) Professor Frank W. Schmidt.
(*d*) Numerical techniques.
(*e*) Numerical solutions of turbulent natural convection systems to determine velocity and temperature profiles and rates of heat transfer.

141-08230-070-00

ISOTHERMAL AND NON-ISOTHERMAL GAS FLOW THROUGH FINE PORED MEDIA

(*b*) Ordnance Research Laboratory (E and F funded) at Penn. State University.
(*c*) Professor Carl H. Wolgemuth.
(*d*) Theoretical and experimental; applied research; Masters and Doctoral theses.
(*e*) The work was undertaken to provide an analytical model for gas flow through the porous electrode of a molten salt fuel cell in the presence of a temperature gradient. An analytical model consisting of two parts was developed. The first part modeled the porous medium and the second part described the three flow regimes, continuum, slip, and free molecule. An experimental system was designed and built to collect data on fuel cell grade porous carbons with

a permeability range from .2 to 1200 cm^2/min., and a temperature gradient range of ± 100°C/cm. The Scanning Electron Microscope was used in addition to mercury penetration tests to determine the pore size distributions of the carbon. Gases over a wide range in molecular weight and viscosity were used in the tests.

(*f*) The project is essentially completed at this time.

(*g*) A simple model of non-isothermal geseous flow through a fine pored medium was developed. The model is applicable over the entire Knudsen number range. A new probabilistic model of the porous medium, which allows flow resistance parameters to be determined solely from cumulative porosity data, was also developed. A permeability range covering three orders of magnitude was experimentally investigated over a Knudsen number range of .1 to 100 for several porous carbons. Good agreement between the experimental data and the analytical model was obtained.

(*h*) **Non-Isothermal Gaseous Flow Through Fine Pored Media,** M. H. Somerville, *Ph.D. Thesis*, Penn. State University, Mar. 1972, available University Microfilms.

PENNSYLVANIA STATE UNIVERSITY, Institute for Science Engineering, Ordnance Research Laboratory, P.O. Box 30, University Park, Pa. 16801. J. C. Johnson, Laboratory Director.

142-02832-030-22

MEASUREMENT OF FORCES AND PRESSURES ON A MODEL IN A WATER TUNNEL

(*b*) Naval Ordnance Systems Command.

(*c*) Mr. George B. Gurney.

(*d*) Experimental and developmental.

(*e*) The problem concerns the measurement of thrust, torque body forces, and pressures on various hydrodynamic bodies. Measurements are made on bodies over a range of velocities up to 60 ft/sec and under pressure simulating fully developed cavitating flows.

(*g*) Strain gaged force balances are used to sense body forces. These balances are capable of completely submerged operation. A Planar Motion Mechanism is available for determining dynamic stability derivatives required in the equation of motion of submerged bodies. The capability of measuring unsteady thrust is also available.

(*h*) **The Garfield Thomas Water Tunnel,** A. F. Lehman, *ORL Unclassified External Rept. NOrd 16597-56*, Sept. 1959.

142-03807-230-50

THERMODYNAMIC EFFECTS ON CAVITATION

(*b*) National Aeronautics and Space Administration.

(*c*) Dr. J. William Holl.

(*d*) Experimental and theoretical.

(*e*) Investigations are carried out in the high speed cavitation tunnel employing various working fluids. At the present time, the primary fluid is Freon 113. Thermodynamic effects are investigated for both developed and limited cavitation over a range of temperatures and velocities. Analytical investigations are also being conducted.

(*h*) **Thermodynamic Effects on Desinent Cavitation on Hemispherical Nosed Bodies in Water at Temperatures from 80 Deg. F. to 260 Deg. F.,** J. W. Holl, A. L. Kornhauser, *Trans. ASME, J. Basic Engrg.*, Mar. 1970.
Thermodynamic Effects on Developed Cavitation in Water and Freon 113, M. L. Billet, *Master's Thesis*, Dept. of Aerospace Engrg., Penn. State Univ., Mar. 1970.

142-06557-240-22

CHARACTERISTIC VIBRATIONS AND ACOUSTIC RADIATION FROM SHELLS OF ARBITRARY SHAPE

(*b*) Naval Ordnance Systems Command.

(*c*) Dr. Maurice Sevik, Director, Garfield Thomas Water Tunnel.

(*d*) Experimental and theoretical.

(*e*) A study of propulsor blade vibrations.

(*g*) An important problem in naval architecture as well as in aircraft engineering concerns the vibrations and noise generated by the propulsion system. In marine applications, the dominant source of vibrations is the propeller. Due to its response to a spatially and temporally nonuniform velocity field within which it operates, the propeller exerts time-dependent axial and side forces, as well fluctuating torques and moments upon the hull of a ship. In recent years, the above-mentioned forces and couples have been the subject of much theoretical and experimental research. In particular, unsteady lifting surface theories such as that of Tsakonas have developed and have accurately predicted experimental results, in many cases. The necessity for minimizing unsteady forces and, hence, vibrations levels, however, has led to the adoption of propeller blades with a high degree of skew. Such blades are more flexible than conventional ones so that hydroelastic effects become of prime importance. The dynamic response of the blades may either alleviate or worsen the net forces and couples. This is the reason which has instigated the present study. The problem has been approached directly by extending the linearized three-dimensional lifting surface theory of Tsakonas to include the effects resulting from the elastic deformation of the blades. The predictions have been verified experimentally on a three-bladed, skewed propeller used by Boswell in a previous investigation. Good agreement between predicted and measured values of the forces have been observed.

(*h*) **Time-Dependent Forces and Moments on Propellers Operating in a Spatially Varying Velocity Field Based on Two-Dimensional, Unsteady Airfoil Theory,** D. E. Thompson, *ORL Internal Memo.*, *File No. 71-184*, Aug. 30, 1971.
State-of-the-Art Report on Propeller-Induced Time-Dependent Forces, D. E. Thompson, *16th Amer. Towing Tank Conf.*, *Inst. de Pesquisas Tecnologicas*, *Sao Paulo*, *Brazil*, Aug. 1971.
The Response of a Propulsor to Random Velocity Fluctuations, M. Sevik, *ORL External Rept.*, *Serial No. N00017-70-C-1407-2*, Apr. 30, 1970.

142-06558-050-22

MIXING OF GASES IN LIQUID JETS

(*b*) Naval Ordnance Systems Command.

(*c*) Dr. Maurice Sevik.

(*d*) Experimental, theoretical; basic research.

(*e*) A study of the bubble formation process in a turbulent jet and the resulting acoustic radiation.

(*f*) Completed.

(*g*) The formation of gas bubbles emitted from a nozzle in a liquid medium has been reviewed and new data obtained in this investigation have been correlated with those published in the past. Several flow regimes have been identified and defined. Bubble diameters varying from 2 to 10 times the orifice diameter can be formed depending on the values of the Weber and Froude numbers of the flow. The work of Hinze concerned with the splitting of drops and bubbles by turbulent flow has been extended. In particular, the break-up of air bubbles in the adjustment region of a high Reynolds number water jet has been observed. A critical Weber number of 1.3 was obtained from these experiments, whereas Hinze calculated a value of 0.59 based on tests involving the splitting of drops of oil in turbulent water. It was found that both Weber numbers could be predicted theoretically by considering the resonances of the drop and gas bubbles.

(*h*) **The Formation and Break-Up of Drops and Bubbles by Turbulent Fluid Flow,** S. H. Park, *Ph.D. Thesis*, Dept. of Aerospace Engrg., Dec. 1971.

142-07568-230-22

THE EFFECT OF SURFACE CHARACTERISTICS ON LIMITED CAVITATION

(*b*) Naval Ordnance Systems Command.

(*c*) Dr. J. William Holl.
(*d*) Experimental and theoretical.
(*e*) The effect of various surface characteristics such as porosity and contact angle on incipient and desinent cavitation is being studied in a water tunnel.
(*f*) Inactive.
(*h*) **The Influence of Porosity and Contact Angle on Incipient and Desinent Cavitation,** S. K. Gupta, *Master's Thesis*, Dept. of Aerospace Engrg., Penn. State Univ., Dec. 1969.

142-07569-230-21

CAVITATION INCEPTION CHARACTERISTICS OF REAL SURFACE ROUGHNESSES

(*b*) Naval Ship Research and Development Center.
(*c*) Dr. J. William Holl; Dr. R. E. Arndt, 233-C Hammond Building.
(*d*) Experimental and theoretical.
(*e*) Problem concerns the cavitation characteristics of real surface roughness such as barnacles. Cavitation tests are to be conducted in a water tunnel and roughnesses are researched in the field.
(*f*) Completed.
(*h*) **The Influence of Surface Irregularities on Cavitation: Field Study and Limited Cavitation Near Wire Screen Roughness,** W. T. Bechtel II, *Master's Thesis*, Dept. of Aerospace Engrg., Penn. State Univ., June 1971.

142-07570-550-22

INVESTIGATION OF FLUCTUATING BLADE SURFACE PRESSURES

(*b*) Naval Ordnance Systems Command.
(*c*) Mr. E. P. Bruce.
(*d*) Experimental and theoretical.
(*e*) Measurement of unsteady blade surface pressures on both rotating and stationary blade surfaces. An axial flow research fan has been designed whose dimensions are of sufficient size to permit installation of high response pressure tranducers along the blade chord. With selected inflow distortions or turbulence levels, the time-dependent blade surface pressures will be measured. A correlation between the experimental results and a number of existing theoretical models will be attempted. In addition, an effort to develop a more representative analytical solution to the unsteady cascade flow problem is in progress.

142-07571-550-22

EXPERIMENTAL INVESTIGATION OF CASCADE GEOMETRIES

(*b*) Naval Ordnance Systems Command.
(*c*) Messrs J. R. Ross and W. S. Gearhart.
(*d*) Experimental and applied research.
(*e*) The development of blading having superior hydrodynamic performance has required the use of cascade geometries for which no experimental data exists. On this basis, a subsonic porous wall cascade tunnel with an aspect ratio of two was designed and made operational. Trailing edge loaded profiles of high chord to spacing ratios are being tested.
(*f*) Inactive.
(*h*) **Two-Dimensional Cascade Tests of a Compressor Blade Designed by the Mean-Streamline Method,** W. S. Gearhart, J. R. Ross, *ORL TM 71-32*, Penn. State Univ., Feb. 1971.

142-07572-550-22

CORRELATION BETWEEN FLUCTUATING BLADE PRESSURES AND RADIATED NOISE IN AXIAL FLOW COMPRESSORS

(*b*) Naval Ordnance Systems Command.
(*c*) Mr. D. E. Thompson.
(*d*) Experimental and theoretical.
(*e*) Due to the operation of the blading of axial flow turbomachines in distorted and turbulent inflows, unsteady blade pressures exist. These fluctuating blade pressures generate sound which is ultimately radiated to the far field. For various inflow conditions, i.e., distorted circumferential velocity distributions, and turbulence of different intensities and eddy sizes, the fluctuating blade pressures will be measured and correlated with simultaneous measurements of the radiated sound. The axial flow compressor is designed to permit tests at various operating conditions, i.e., rotor-stator spacing, rotor rpm, etc. Where the inflow and compressor characteristics match the assumptions used in a particular theory designed to predict the acoustic radiation from such a turbo-machine, an attempt will be made to correlate the experimental and theoretical results.

142-07573-550-22

AN INVESTIGATION INTO UNSTEADY PROPULSOR FORCES

(*b*) Naval Ordnance Systems Command and Naval Ships Systems Command.
(*c*) Messrs F. E. Smith and D. E. Thompson.
(*d*) Experimental and theoretical.
(*e*) Propulsors experience unsteady forces due to operation in the wakes shed from control surfaces and due to operation in a turbulent inflow. An investigation is in progress whose purpose is to measure the unsteady propulsor forces accurately and correlate these measurements with theoretically determined values. An investigation will then be made into the effects of various propulsor configurations, i.e., number of blades, advance ratio, etc., and the effects of varying the inflow charcteristics. Two types of propulsors, a propeller and a pumpjet, are being studied. Both are operated in the free stream in order that the complex inflow, that would be present when an upstream body exists, is eliminated. An attempt will be made to correlate the experimental and theoretical results. This investigation also includes the measurement of unsteady propulsor forces due to operation in the complex wake behind an underwater vehicle.
(*h*) **Time-Dependent Forces and Moments on Propellers Operating in a Spatially Varying Velocity Field Based on Two-Dimensional, Unsteady Airfoil Theory,** D. E. Thompson, *ORL Internal Memo., File No. 71-184*, Aug. 1971.
State-of-the-Art Report on Propeller-Induced Time-Dependent Forces, D. E. Thompson, *16th Amer. Towing Tank Conf., Inst. de Pesquisas Tecnologicas, Sao Paulo, Brazil*, Aug. 1971.
The Response of a Propulsor to Random Velocity Fluctuations, M. Sevik, *ORL External Rept., Serial No. N00017-70-C-1407-2*, Apr. 1970.
Dynamic Response of an Elastic Propeller to a Non-Uniform Inflow, H. Tsushima, *Ph. D. Thesis*, Dept. of Aerospace Engr., Penn. State Univ., June 1972.

142-08231-050-00

HIGH VELOCITY WATER JETS

(*c*) Dr. Walter F. King III.
(*d*) Theoretical and experimental, applied research.
(*e*) An experimental and theoretical study will be made of high-velocity water jets. The investigation will include nozzle effects, velocity profiles, polymer additives, and jet impact parameters.
(*g*) Experimental phase of the project has not yet begun; some theoretical results are as reprints.
(*h*) **Hydrodynamics of Explosively Generated High-Velocity Fluid Jets,** J. L. Politzer, W. F. King III, *J. Appl. Phys.* **42,** 5, 2095-99, 1971.
Dynamics of High-Velocity Jet Generation with Compressible Liquids, W. F. King III, J. L. Politzer, *J. Appl. Phys.*, May 1972.

142-08232-050-22

JET NOISE ATTENUATION

(*b*) Naval Ordnance Systems Command.
(*c*) Dr. R. E. A. Arndt.
(*d*) Experimental and theoretical.

(e) The introduction of a screen into a jet flow results in substantial noise reduction. Far field studies include directivity and power spectrum. Near field studies include turbulence intensity, space time correlation and spectrum of the velocity field. Theoretical analysis is used to correlate the near field data with observed attenuation in the far field.

142-08233-050-22

TURBULENCE CHARACTERISTICS OF PERTURBED AND UNPERTURBED JETS

(b) Naval Ordnance Systems Command.
(c) Dr. R. E. A. Arndt.
(d) Experimental and theoretical.
(e) Open jet wind tunnels are currently being used for aeroacoustic research. This permits enclosure of the jet in an anechoic chamber, thus eliminating some of the reverberation problems inherent in closed jet facilities. Little is known about the effect of a test body on the turbulence characteristics in the mixing zone of a jet. Detailed probing with hot wires and pressure instrumentation is used to determine the mixing characteristics of perturbed and unperturbed jets. Measurement of the near field pressure is used to determine the strength of acoustic sources.

142-08234-540-22

ROTOR NOISE ATTENUATION WITH LEADING EDGE DEVICES

(b) Naval Ordnance Systems Command.
(c) Dr. R. E. A. Arndt.
(d) Experimental and theoretical.
(e) The quiet flight of an owl encourages one to look closer at his wing to determine the mechanism by which this silent flight is achieved. Unlike all other birds, the owl is equipped with leading and trailing edge combs of closely spaced teeth. The use of a similar device on the leading edge of a rotor results in a substantial noise attenuation. This is a study of the near field and far field characteristics of the noise signal to determine the mechanism of attenuation. Turbulence and flow visualization studies complement the acoustic data.

142-08235-230-20

VORTEX CAVITATION

(b) Office of Naval Research.
(c) Dr. J. William Holl; Dr. Roger E. A. Arndt.
(d) Experimental and theoretical.
(e) Study various forms of limited cavitation in vortex flows, i.e., vaporous and non-vaporous cavitation; noise characteristics; basic flow field.

142-08236-230-22

THE EFFECT OF POLYMER ADDITIVES ON CAVITATION

(b) Naval Ordnance Systems Command.
(c) Dr. Roger E. A. Arndt; Dr. J. William Holl.
(d) Experimental and theoretical.
(e) Determine the effect of polymer additives on cavitation in a shear flow.

142-08237-290-22

DETECTION OF SOUND SOURCES USING ACOUSTICAL HOLOGRAPHY

(b) Naval Ordnance Systems Command.
(c) Dr. E. Eugene Watson.
(d) Experimental, theoretical, applied research.
(e) Detection of sound sources using acoustical holography enables the experimenter to localize these sources by scanning the acoustic far field on the vibrator. This method is rapid and accurate compared to conventional methods and reveals a unique approach to analyzing the sound radiation from complex vibrators such as ribbed plates and cylindrical bodies.
(f) Initial investigation completed; seeking new funds for extension.
(g) Sound radiation from vibrating baffled and unbaffled circular steel plates has been detected and their sources located on the plates. Radiation sources from ribbed rectangular plates have also been localized.
(h) **Detection of Sound Radiation from Plates Using Long Wavelength Acoustical Holography**, *Ph.D. Thesis*, Penn. State Univ., 1971.
Detection of Acoustic Sources Using Long Wavelength Acoustical Holography, to be published in *J. Acoustical Soc. America*.

UNIVERSITY OF PITTSBURGH, School of Engineering, Chemical and Petroleum Engineering Department, Pittsburgh, Pa. 15213. Dr. George E. Klinzing, Associate Professor.

143-07575-250-00

TURBULENT GAS DRAG REDUCTION IN FLEXIBLE TUBES WITH SOLID ADDITION

(d) Experimental and theoretical; basic and applied research; Doctoral thesis.
(e) Determination of the possible drag reduction caused by a coupling of two drag reducing measures by overall measurements and turbulence structures.
(g) A model based on a continuum was found to predict the data taken on the two-phase turbulent flow of a gas-solid system to loading ratios of 7 lb solids/lb gas. Particles of 25μ and 50μ were investigated in rigid and flexible tubes. True drag reduction was found in only the 25μ size particles. The tension effects showed an optimum value for drag reduction. Electrostatic effects on flexible tube studies showed pronounced increases in pressure drops. The combination of solid addition and flexible boundary expanded the range of power changes found in the two-phase flow studies in rigid tubes. Hot-wire anemometer studies indicate a modification of the turbulence intensities by the presence of the flexible boundary and solids to the air system.
(h) *Ph.D. Thesis*, L. Peters, Univ. of Pittsburgh, July 1971.
M.S. Thesis, D. Bender, Univ. of Pittsburgh, Dec. 1971.
Paper accepted for publication in *Canad. J. Chem. Engrg.*, 1972.

143-08238-000-00

LAMINAR FLOW INSTABILITY IN PARALLEL CONVECTION COUPLED CHANNELS

(d) Experimental and theoretical; basic and applied research; Doctoral thesis.
(e) The laminar flow instability exhibits itself as a flow rate excursion in single isolated tubes having a negative pressure drop/flow rate derivative at constant heat addition. This usually occurs in the laminar Reynolds number range, or in a gas which has viscosity increasing with temperature and has a turbulent-to-laminar transition within the channel. The instability and its effects on the nuclear rocket design are given. It is suspected that if parallel channels can transfer heat from one to the next by means of convective heating from the hotter channel, the stability characteristics are different. Flow-to-heat flux transfer functions have been derived for the two channel, axially averaged case which indicate a possible oscillatory mode in addition to the excursion mode. A proposal is made to investigate this temperature-flow instability, both analytically and numerically. The primary purpose is to develop stability criteria for the multi-channel coupled case and to compare the results with the isolated single channel case. Also, the effect of end pressure losses and a sonic nozzle are to be studied for the single channel.
(g) The effect of variable physical properties on the flow system with a constant heat flux is seen to drive the flow to zero at zero pressure drop in the model.
(h) Anticipated *Ph.D. Thesis*, D. Black, Univ. of Pittsburgh.

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UNIVERSITY OF PITTSBURGH, Department of Civil Engineering, Water Resources Program, Pittsburgh, Pa. 15213. Professor Chao-Lin Chiu, Program Chairman.

144-08239-300-54

STOCHASTIC SIMULATION IN STUDY OF FLOW IN IRREGULAR NATURAL STREAMS AND RIVERS

(*b*) National Science Foundation.
(*d*) Analytical, experimental.
(*e*) Stochastic modeling of irregular channel geometry to simulate irregular cross-sections and slopes of a stream, and development of numerical techniques for coupling the stochastic simulation of irregular channel geometry with existing deterministic system models of transport processes in a stream.
(*g*) A stochastic model has been developed to simulate irregular cross-sections and slopes of a stream.
(*h*) **Stochastic Methods in Hydraulics and Hydrology of Streamflow,** C.-L. Chiu, *J. Geophysical Surveys* **1,** 1, Sept. 1972.

144-08240-810-54

STOCHASTIC HYDROLOGIC SYSTEMS

(*b*) National Science Foundation.
(*c*) Dr. Rafael G. Quimpo.
(*d*) Theoretical with field investigation and data analysis.
(*e*) Stochastic models of hydrologic systems are investigated with a view of unifying their formulation under a common framework with models of parametric hydrology.
(*h*) **Kernels of Stochastic Linear Hydrologic Systems,** *Proc. 1st U.S.-Japan Bilateral Seminar on Hydrology*, Honolulu, Hawaii, Jan. 1971.
Structural Relations Between Stochastic and Parametric Hydrology Models, *Proc. Intl. Assoc. Sci. Hydrol., Intl. Symp. on Mathematical Models in Hydrology*, Warsaw, Poland, July 1971.
Stochastic Extension of the Unit Hydrograph Theory, *EOS, Trans. Amer. Geophys. Union* **52,** 11, Nov. 1971.
Simulation Studies on the Variability of Amplitudes and Phases in Hydrologic Time Series, (with M. S. Cheng), *EOS, Trans. Amer. Geophys. Union* **53,** 4, Apr. 1972.

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PRINCETON UNIVERSITY, Department of Civil and Geological Engineering, School of Engineering and Applied Science, Princeton, N.J. 08540. Ahmet S. Cakmak, Department Chairman.

145-08246-000-00

STABILITY OF FREE SHEAR LAYERS

(*c*) Professor George E. Mattingly or J. Tracy.
(*d*) Experimental and theoretical; basic research, Doctoral thesis.
(*e*) Applying linear stability analysis to various flow fields to determine the character of the destabilization. These results give information on the type of stimulation that would be most effective in artificially destabilizing the motion or in avoiding such destabilization. For several of the flow fields examined the analysis has been conducted experimentally (see publications in (h) below) while others have only been treated theoretically (see(h)).
(*g*) Results to date have indicated that these analyses are most properly done using the complex wave-number model which is also referred to as the spatial stability viewpoint. Further, in each case the results have correctly indicated the general character of the destabilization and the equilibrium state of motion ultimately achieved.
(*h*) **Disturbance Characteristics in a Plane Jet,** G. E. Mattingly, W. O. Criminale, *Physics of Fluids* **14,** 11, pp. 2258-2264, Nov. 1971.
The Stability of an Incompressible Two-Dimensional Wake, G. E. Mattingly, W. O. Criminale, *J. Fluid Mech.* **51,** 2, pp. 233-272, Jan. 1972.
The Spatial Instability of an Axisymmetric Jet, C. C. Chang, G. E. Mattingly (in preparation).

145-08247-000-54

THE DYNAMICS OF VORTEX TUBES

(*b*) National Science Foundation.
(*c*) Professor George E. Mattingly or G. Shepard.
(*d*) Experimental, basic research which is readily applied to practical situations.
(*e*) Experiment is directed at the quantitative determination of the dynamics of vortex rings and examines their unique transport mechanism and their ability to penetrate density layers against buoyant forces.
(*g*) Results to date indicate that it might be possible to replace conventional smoke stacks with vortex ring generators which could shoot effluent gases to greater heights and even through atmospheric inversion layers which act as a barrier to conventional buoyantly driven smoke stack dispersal systems. Vortex rings might also be used to transport oxygenated surface waters through thermoclines in deep lakes and reservoirs to improve deep water quality. Vortex rings might be used as an artificial breakwater by being shot from depth to a wavy surface.
(*h*) **The Dynamics of Vortex Rings ....,** V. Dougalis, G. E. Mattingly (in preparation).

145-08248-300-00

MATHEMATICAL MODELING OF RIVER SYSTEMS

(*c*) Professor George E. Mattingly.
(*d*) Experimental and theoretical; applied research.
(*e*) Improving the present modeling schemes being applied to river systems. Analyze the phenomena of natural reaeration as it depends upon such important factors as wind and water velocity structure.

145-08249-810-54

HYDROLOGICAL AND GEOCHEMICAL STUDIES OF NEW JERSEY PINE BARRENS RIVERS

(*b*) National Science Foundation.
(*c*) D. J. Kinsman.
(*d*) Field investigation; basic research; Ph.D. thesis.
(*e*) Budgets for water and dissolved chemical species are being determined for rain waters, river waters and groundwaters of the Pine Barrens; the roles of biological and geological processes are being determined. The aim of the project is to understand the naturally occurring processes affecting the hydrochemistry of the area.
(*g*) Rain water input accounts for all rain water discharge of CL^-, No^+, K^+, Ca^{++} and Mg^{++}; rock-water reactions add ion and silicon. Rates of loss of iron from the area require extensive cross-formational leakage of groundwater to be occurring from deeper aquifers.
(*h*) **Hydrological and Geochemical Studies of New Jersey Pine Barrens Rivers,** H. M. Kelsey, D. J. J. Kinsman, *Geol. Soc. Amer. Abst.* **3,** 7, p. 621, 1971.

145-08250-030-00

DETERMINATION OF AERODYNAMIC COEFFICIENTS OF SUSPENSION BRIDGES

(*c*) Professor R. H. Scanlan and J-G. Beliveau.
(*d*) Experimental determination of aerodynamic coefficients of two-dimensional suspension bridge models utilizing method of nonlinear least squares.
(*e*) Previous wind tunnel tests in suspension bridge models have been run at many different wind velocities in order to determine the effects of the aerodynamics on the quasi-steady coefficients of the differential equations. A method is proposed to determine the same information from one wind tunnel test at varying velocity.

(*f*) Data has been acquired at Fairbanks Laboratories of Federal Highway Administration in McLean, Va., and portions have been digitized.
(*g*) A numerical version of final program is successfully determining the coefficient from a generated test case. The generalization to vortex forcing functions, and the results of real bridge model data is being programmed.
(*h*) **Airfoil and Bridge Flutter Derivatives,** R. H. Scanlan, J. J. Tomko, *J. Engrg. Mech. Div., ASCE*, pp. 1717-1737, Dec. 1971.

145-08251-870-00

PARAMETER IDENTIFICATION IN BIOCHEMICAL OXYGEN DEMAND AND DISSOLVED OXYGEN DEFICIT EQUATION IN STREAMS

(*c*) Professor R. H. Scanlan or J-G. Beliveau.
(*d*) Applied research in obtaining coefficients of differential equations in BOD-DO dynamic equations utilizing nonlinear least squares. Experimental data will be generated by computer if real data is not available.
(*e*) In order to control effluents into rivers or streams of various facilities, quantitative rather than qualitative evaluation of the pollution load capability of such streams is required. The method used, nonlinear least squares, allows for such an evaluation from observed field data of BOD and DO. The parameters to be identified are the coefficient of deoxygenation, reaeration, and sedimentation, the effect of photosynthesis, BOD from bottom deposits, and also the coefficient of longitudinal dispersion.

145-08252-820-00

WATER RESOURCES AND LAND-USE PLANNING IN RAPIDLY URBANIZING AREAS IN NEW JERSEY

(*c*) Professor William E. Bonini.
(*d*) Field investigation; applied research, Doctoral thesis.
(*e*) Rapid present and potential urbanization in the New York-Philadelphia corridor does and can produce long range effects on recharge of the most important aquifers in the area. Research is designed to locate those zones of critical importance for recharge, so that this information can be used in land-use planning to protect this resource.

145-08253-860-00

FORECASTING AND CONTROL OF A TRIBUTARY SYSTEM

(*c*) Professor J. Stuart Hunter.
(*d*) Field investigation; applied research.
(*e*) To construct a system model for forecasting water quality responses at a water treatment plant, and to control these responses using, in part, released reservoir flows. Time series records on streamflow responses for two streams and their confluence will be used to construct a deterministic-stochastic system model.
(*g*) Initial stream modeling now underway.

145-08254-070-00

FLUID FLOW IN FRACTURED POROUS MEDIA

(*c*) Professor P. C. Y. Lee or James Duguid.
(*d*) Theoretical, basic and applied research; Doctoral thesis.
(*e*) A set of governing equations for fluid flow through fractured porous media is derived. In addition to the usual primary permeability (isotropic), the fluid conductivity due to an anisotropic fracture distribution is taken into account. The interaction of fluid in the primary pores with the fluid in the fractures (i.e., flow from pore to fracture) is incorporated in this formulation. A numerical program using the Galerkin method in conjunction with finite elements is being developed for solving the set of coupled equations.

PURDUE UNIVERSITY, Department of Agricultural Engineering, Lafayette, Ind. 27907. Dr. G. W. Isaacs, Department Head.

146-03808-830-05

PREDICTING RUNOFF AND GROSS EROSION FROM FARMLAND AND DISTURBED AREAS. (Also see Agric. Research Serv., Corn Belt Branch, Project 04275).

(*b*) Soil and Water Conservation Div., U.S. Dept. of Agric. and Agric. Experiment Sta., Purdue University.
(*c*) Mr. Walter H. Wischmeier, ARS-SWC.
(*d*) Experimental; development.
(*e*) The relationship of numerous rainstorm characteristics, topographic features, soil characteristics and surface conditions to surface runoff and soil erosion are being evaluated from plot data obtained under natural and/or simulated rainfall.
(*g*) A nomograph was developed which graphically computes the soil-erodibility of the universal soil-loss equation from data on particle-size distribution, organic-matter content, permeability, and structure. A methodical technique for objective evaluation of the equation's cover factor, C, for pasture, range and woodland conditions for which erosion research data are not available was developed. The cover effect was subdivided into three zones of influence (at, above, and beneath the soil surface) and known parameter relationships were applied to each component. Mulches of crushed stone, gravel or woodchips were found more effective than straw for erosion control on denuded 20 percent construction slopes, and revegetation was quite successful where effective rates of these mulches had been used.
(*h*) **A Soil-Erodibility Nomograph for Farmland and Construction Sites,** W. H. Wischmeier, C. B. Johnson, B. V. Cross, *J. Soil Water Cons.* **26**, 5, 189-193, 1971.
Erosion, Runoff, and Revegetation of Denuded Construction Sites, L. D. Meyer, W. H. Wischmeier, W. H. Daniel, *Trans. Amer. Soc. Agric. Engrs.* **14**, 1, 138-141, 1971.

146-04182-830-05

MECHANICS OF SOIL EROSION BY WATER (Also see Agric. Research Serv., Corn Belt Branch, Project 04275).

(*b*) Soil and Water Conservation Research Div., Agricultural Research Service, U.S. Dept. of Agric., and Agric. Experiment Sta., Purdue University.
(*c*) Dr. L. D. Meyer, ARS-SWC.
(*d*) Experimental, analytical, basic research.
(*e*) The mechanics of soil erosion by water are being studied as a basis for mathematically simulating the soil erosion process.
(*g*) The soil erosion process was mathematically simulated by considering soil detachment and transport by rainfall and runoff as separate but interrelated subprocesses. Relationships to describe these processes are being developed based on published information, laboratory experiments and field tests.
(*h*) **A Closed-Form Soil Erosion Equation for Upland Areas,** G. R. Foster, L. D. Meyer, *Sedimentation*, H. W. Shen, Editor, pp. 12-1 to 12-19, 1972.
Turbulence Characteristics of Overland Flow–The Effects of Rainfall and Boundary Roughness, I. T. Kisisel, A. R. Rao, J. W. Delleur, L. D. Meyer, *Water Resources and Hydromechanics Lab. Tech. Rept. 28*, Purdue Univ., 145 p., 1971.
Soil Erosion by Water on Upland Areas, L. D. Meyer, *River Mechanics*, H. W. Shen, Editor, pp. 27-1 to 27-25, 1971.

146-07584-820-61

WATER QUALITY CONTROL IN THE SOIL ECOSYSTEM

(*c*) Dr. E. J. Monke.
(*d*) Experimental, theoretical, field investigation, applied research.

(*e*) To study the dynamics of water and pollutant movement in unsaturated soil, to study the role of plant life in water quality management, and to evaluate treatment of polluted water by filtration through the soil mantle.
(*g*) Work is progressing toward the study of soil pollutants in an unsaturated flow regime. Recent studies concerned the effect of root and ambient air temperature differences on tomato plant growth and three-dimensional flow through drain openings using an electrolytic model.
(*h*) **An Approximate Method for Defining the Hydraulic Conductivity-Pressure Potential Relationship for Soils,** R. W. Skaggs, E. J. Monke, L. F. Huggins, *Trans. Amer. Soc. Agric.Engrs.* **14,** 1, 130-133, 1971.
Movement of Pollutant Phosphorus in Saturated Soils, P. R. Goodrich, E. J. Monke, *Proc. Intl. Symp. on Livestock Wastes* (Publ. by Amer. Soc. Agric. Engrs.), pp. 325-328, 1971.
Three-Dimensional Electrolytic Model of Flow Through Drain Openings, H. Yap-Salinas, *M.S. Thesis*, Purdue Univ., 1971.

146-07585-810-33

CHARACTERIZATION OF THE HYDROLOGY OF SMALL WATERSHEDS

(*b*) Office of Water Resources Research, and Agricultural Expt. Sta., Purdue University.
(*c*) Dr. L. F. Huggins.
(*d*) Experimental, basic, applied, design.
(*e*) Develop an analytical method to accurately describe the hydrologic response of natural watersheds to real or hypothetical storms independent of gaged records for a watershed.
(*g*) Present efforts are being directed toward improving the characterization of overland flow processes and toward the development of more efficient computer programs to implement the model for watersheds up to 10 sq. mi. in size.
(*h*) **Mechanics of Flow Over Very Rough Surfaces,** P. S. Kundu, *Ph.D. Thesis*, Purdue Univ., 1971.

PURDUE UNIVERSITY, Department of Agronomy, Lafayette, Ind. 47907. Dr. M. W. Phillips, Department Head.

147-0122W-810-00

ELECTRICAL EFFECTS ON WATER INFILTRATION INTO SOILS

(*e*) For summary, see *Water Resources Research Catalog* **5,** 1.0056 and 2.0525.
(*f*) Completed.
(*g*) For water-saturated conditions, electrical potential arising from water flow through a sand-kaolinite mixture could only be measured consistently as a step change in electrical potential at the time of initiation or cessation of hydraulic flow. The direction of this "E step" was consistent with streaming-potential phenomena. The magnitude of the E step was essentially proportional to the hydraulic gradient, in conformity with classical double-layer theory. Similar measurements were made on water-saturated plugs of sodium bentonite at five different clay concentrations ranging from 11.5 to 35.1 percent clay. At 11.5 percent, both the water flux and the E step responded less than proportionally to the hydraulic gradient, but both responses became proportional at 28.4 percent clay. In general, anomalous E-step behavior could not be said to cause more-than-proportional flux-gradient response. Finally, for the unsaturated upward entry of water into initially dry sand-kaolinite, the qualitative and quantitative progress of the wet front could be monitored rather well by the negative-peak response of electrical potential measurements.
(*h*) **Electrical Effects and the Movement of Water in Soils,** D. Swartzendruber, S. Gairon, *Tech. Rept. 13*, Purdue Univ. Water Resources Research Center, Lafayette, Ind., 40 pp., July, 1970.

147-0123W-810-00

QUANTIFICATION AND PREDICTION OF THE INFILTRATION PHASE OF THE HYDROLOGIC CYCLE

(*e*) For summary, see *Water Resources Research Catalog* **5,** 2.0526.
(*f*) Completed.
(*g*) The validity of unsaturated soil-water flow theory was studied by measuring transient water contents by gamma-ray attenuation on horizontal columns of silty clay loam into which water was being absorbed. Persistent deviations from theory could be observed for columns at bulk densities of 1.08 and 1.22 g/cc, thus indicating that deviations at the low bulk density were not being caused by particle rearrangements correctable by the tighter packing at the higher bulk density. For the wetting phase of water redistribution in both the silty clay loam and a kaolinite-sand silt mixture, gamma-ray measurements of transient water contents were used to determine experimental plots of water flux versus hydraulic gradient. Within an appreciable scatter of points, no consistent departures from theoretically required proportionality were observed. Although the resulting calculations of soil-water diffusivity exhibited 10-fold variations, two averaging processes were found for which the mean diffusivities determined on duplicate soil columns were always well within 2 fold of each other.
(*h*) **Horizontal Entry and Redistribution of Soil Water,** D. L. Nofziger, D. Swartzendruber, M. L. Sharma, *Tech. Rept. 12*, Purdue Univ. Water Resources Res. Center, Lafayette, Ind., 41 pp., Mar. 1971.

147-0124W-810-00

DYNAMICS OF WATER INFILTRATION INTO SOIL AS GOVERNED BY SURFACE

(*e*) For summary, see *Water Resources Research Catalog* **6,** 2.0682.
(*h*) **An Improved Form of Soil-Water Diffusivity Function, L.** R. Ahuja, D. Swartzendruber, *Soil Sci. Soc. Amer. Proc.* **36,** 1, pp. 9-14, 1972.

147-07586-810-33

MOVEMENT AND RETENTION OF WATER IN SOILS AND POROUS MEDIA

(*b*) Agricultural Experiment Station, Purdue Univ., and Office of Water Resources Research.
(*c*) Dr. Dale Swartzendruber.
(*d*) Experimental and theoretical; basic research, for Master's and Doctoral theses.
(*e*) The flux of soil water in response to gradients of potential and water content is being studied and measured for both rigid and swelling porous media and soils. The range of validity of flux-gradient equations and their related boundary-value problems and solutions is being tested, and feasible evaluations of the parameters in them are being sought, to enable better characterization and prediction of the soil-water phase of the hydrologic cycle under conditions of both saturated and unsaturated flow.
(*g*) Under water-saturated conditions, the spontaneous movement of water against a hydraulic gradient in a mixture of 5 percent bentonite in 95 percent sand and silt has been found to be associated with a gradient of salt concentration in the system, as presumably caused by the infiltration of water during the original wetting of the porous material in the process of saturating it with water. Under unsaturated conditions, single gamma-ray measurements of transient soil-water contents have been analyzed by computer to evaluate the flux-gradient relationship independently of the boundary conditions under which water entry takes place. Many values of soil-water diffusivity are thus generated, and can be averaged to establish a meaningful diffusivity function. Also, a dual-energy gamma-ray system has been devised to obtain simultaneous measurements of water content and bulk density in transiently wetting systems. Results show that previously observed deviations from flow theory in a silty clay loam soil cannot be attributed to clay swelling.

(*h*) **Flux-Gradient Relationships for Saturated Flow of Water Through Mixtures of Sand, Silt, and Clay,** D. A. Russel, D. Swartzendruber, *Soil Sci. Soc. Amer. Proc.* **35**, 1, pp. 21-26, 1972.
Factors Influencing Water Transport Properties of Particulate Mixtures Containing Swelling Clay, G. Y. Tsuji, *Ph.D. Thesis*, Purdue Univ. Library, June, 1971.

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PURDUE UNIVERSITY, School of Chemical Engineering, Lafayette, Ind. 47907. Professor Robert A. Greenkorn, Head, School of Chemical Engineering.

148-06781-070-54

FLOW REGIMES AND FLOW THROUGH POROUS MEDIA

(*b*) National Science Foundation.
(*d*) Experimental, theoretical, basic; M.S. and Ph.D. theses.
(*e*) Determine theroretically and experimentally the flow regimes and their dynamical range for flow in porous media. A creeping flow regime (Darcy's law is valid) is usually assumed for flow in porous media. However, it may be owing to pressure transients or changes in properties of the bed that other flow regimes are present. A first approach to determine flow regimes might be to study the response of fluid-filled packed beds to pressure oscillations. Theoretical models such as the wave equation for a viscous fluid in porous media might be used to determine possible regimes.
(*h*) **Flow Regimes in Porous Media,** P. G. Smith, *M.S. Thesis*, avaliable Purdue Univ. Library.
Theory of Acoustical Wave Propagation in Porous Media, P. G. Smith, R. A. Greenkorn, *J. Acous. Soc.*, Feb. 1972.
The Transient Pressure Response of Rigid Porous Media, P. G. Smith, *Ph.D. Thesis*, available Purdue Univ. Library.

148-06783-070-54

DISPERSION DURING FLOW IN NON-UNIFORM, HETEROGENEOUS, ANISOTROPIC POROUS MEDIA

(*b*) National Science Foundation.
(*d*) Experimental, theoretical, basic; M.S. and Ph.D. theses.
(*e*) To relate the dispersion tensor to properties of the porous media. We have measured dispersion in heterogeneous linear models and are presently engaged in measuring the effect of non-uniformity and anisotropy on dispersion. These measurements will be made in linear and radial glass bead models. Once the measurements are complete we will relate these data to continuous and statistical theories of the media.
(*h*) **A Statistical Model of a Porous Medium With Non-Uniform Pores,** R. E. Haring, R. A. Greenkorn, to be published, *AIChE J.*
On Dispersion in Laminar Flow Through Porous Media. R. D. Patel, R. A. Greenkorn, to be published, *AIChE J.*
Dispersion in Heterogeneous Nonuniform Anisotropic Porous Media, R. A. Greenkorn, D. P. Kessler, *Ind. Eng. Chem.* **61**, 9, 14, 1969.
An Experimental Investigation of a Porous Medium Model with Nonuniform Pores, R. J. Pakula, R. A. Greenkorn, *AIChE J.* **17**, 1265, 1971.
Dispersion During Flow in Linear Heterogeneous Porous Media, R. C. Pleshek, *M.S. Thesis*, available Purdue Iniv. Library.
A Study of Permeability and Dispersion Phenomena in An Anisotropic Porous Medium, E. G. Lenth, *M.S. Thesis*, available Purdue Univ. Library.
Dispersion During Flow in Nonuniform Heterogeneous Porous Media, E. H. Niemann, *M.S. Thesis*, available Purdue Univ. Library.
Permeability and Dispersion During Flow in Linear Heterogeneous Anisotropic Porous Media, T. L. Goad, *M.S. Thesis*, available Purdue Univ. Library.
Permeability and Dispersion in Heterogeneous Anisotropic Consolidated Porous Media, M. B. Moranville, *M.S. Thesis*, available Purdue Univ. Library.

148-06785-130-00

DISPERSION OF DROPS IN PIPE FLOW OF LIQUIDS

(*c*) J. H. Rushton, Professor.
(*d*) Experimental, basic; M.S. and Ph.D. theses.
(*e*) An immiscible liquid is to be injected into a flowing stream of another liquid. Drop size and interfacial area between the phases will be measured by a light transmission technique. Three sizes of main stream tubing are to be used so that different interfacial liquid tensions can be evaluated and other fluid properties varied.
(*h*) **Interfacial Area in Pipes Under Continuous, Turbulent Flow Conditions,** R. F. Henry, *M.S. Thesis*, available Purdue Univ. Library.

148-07588-100-29

TRANSIENT STRESSES IN COUETTE FLOW

(*b*) National Defense Education Act.
(*c*) A. H. Emery, Professor.
(*d*) Experimental, theoretical, basic; M.S. and Ph.D. theses.
(*e*) To measure transient normal stresses in a concentric-cylinder viscometer and compare this with the values obtained on a Weissenberg rheogoniometer, to find the limits of applicability of the concentric cylinder for this purpose. Normal stress results will be compared to predictions of several integral constitutive equations, and the limitations found will be compared to the predictions of some simple constitutive equations.

148-07592-130-00

DRAG REDUCTION IN TWO-PHASE FLOW

(*c*) Professor R. A. Greenkorn or Asst. Professor D. P. Kessler.
(*d*) Experimental, theoretical, basic; M.S. and Ph.D. theses.
(*e*) To measure and correlate drag coefficients in tubes, fittings, pumps, etc., in the laminar, transitional, and turbulent regimes for the annular flow of two liquids plus a suspended solid phase. The outer liquid will be viscoelastic. Experiments will be run in flow slip at Reynolds number up to 100,000. Pressure drop measurements, velocity profiles, and visual observations will be used to postulate mechanisms for such flow and derive predicting equations. The data will be correlated according to these equations.
(*h*) **Drag Coefficients for the Flow of Complex Fluids, T. R. Sifferman,** *Ph.D. Thesis*, available Purdue Univ. Library.
Drag Reduction for Polymeric and Two-Phase Liquid System in Smooth and Rough Pipes, J. F. Coursen, *M.S. Thesis*, available Purdue Univ. Library.
Drag Reduction for Oil-Water Mixtures in Pipes, J. T. Lonsdale, *M. S. Thesis*, available Purdue Univ. Library.

148-07593-070-00

STATISTICAL MODELS OF NON-UNIFORM, ANISOTROPIC POROUS MEDIA

(*c*) R. A. Greenkorn, Professor; D. P. Kessler, Assoc. Professor; J. A. Guin, Visiting Professor.
(*d*) Theoretical, basic; M. S. and Ph.D. theses.
(*e*) Study and develop meaningful models for non-uniform, anisotropic porous media. These models will be used to study the mechanistic nature of flow in porous media. Attempts to study correlations between various dynamical properties in packed beds require understanding relationships between media parameters and parameters of the model. The void space in a packed bed may be described parametrically with simplified statistical models. These models help develop more meaningful theories for dispersion during flow through porous media.

(*h*) **A Statistical Model for Flow in Non-Uniform Anisotropic Porous Media,** R. A. Greenkorn, D. P. Kessler, *Proc. ASCE-EMD Conf. on Probability Concepts and Methods*, 1969.
On Average Pore Velocity in Porous Media, J. A. Guin, D. P. Kessler, R. A. Greenkorn, *Phys. Fluids* **14,** 181, 1971.
On the Permeability Tensor for Anisotropic Non-Uniform Porous Media, J. A. Guin, D. P. Kessler, R. A. Greenkorn, *Chem. Eng. Sci.* **26,** 1475, 1971.
The Dispersion Tensor in Anisotropic Porous Media, J. A. Guin, D. P. Kessler, R. A. Greenkorn, accepted for publication *IEC Fund.*, Mar. 1972.

148-07594-020-00

ENERGY TRANSFER IN HIGH TURBULENCE REYNOLDS NUMBER FLOWS EXHIBITING LOCAL ISOTROPY

(*c*) R. N. Houze, Asst. Professor.
(*d*) Theoretical, basic, M. S. and Ph.D. theses.
(*e*) Analysis of available experimental data taken in a free turbulent air jet. Analysis allows determination of the three-dimensional energy spectrum and the energy transfer spectrum from correlation measurements. The various models for energy-transfer spectrum proposed by various investigators will be compared with the measured spectra under conditions where such a comparison is valid and can yield meaningful results.
(*f*) Completed.
(*g*) Models of energy-transfer spectrum compared with experimental results. Results indicate inadequacy of present models, need for additional data and further study of improved models.
(*h*) **Energy Transfer at High Turbulent Reynolds Numbers,** J. G. Refling, *M. S. Thesis*, available Purdue Univ. Library.

148-07597-130-00

COCURRENT GAS LIQUID FLOW IN PACKED BEDS

(*b*) Purdue Research Foundation–David Ross Grant.
(*c*) D. P. Kessler, Assoc. Professor.
(*d*) Experimental, theoretical, basic; M. S. and Ph.D. theses.
(*e*) This is an experimental and theoretical investigation of cocurrent gas-liquid flow in packed beds with objectives; (1) characterizing slug length and frequency in the pulse flow regime (therefore determining holdup and, to some extent, interfacial area); (2) developing from (1) a model for delta P; (3) developing a dispersion model for this flow regime; (4) developing a model to describe the instability leading to slugging. Variables include gas and liquid velocities, packing size, type and configuration, liquid and gas physical properties, and angle at which the body force acts. Data is taken using shorting probes which detect presence of gas or liquid at any given point. This data is recorded on magnetic tape or read out on a strip chart, and then processed to determine the frequency and velocity of slugs of liquid and the correlation of the presence of liquid at one point in the bed with the presence of liquid at some other point in the bed. This work has aimed primarily at defining pulse geometry and velocity. We wish to continue this work to include dispersion effects.
(*h*) **Liquid-Gas Distribution Measurements in the Pulsing Regime of Two-Phase Cocurrent Flow in Packed Beds,** W. E. Beimesch, *M. S. Thesis*, available Purdue Univ. Library.

148-07598-130-00

ANNULAR AND DISPERSED TWO-PHASE FLOW IN PIPES

(*b*) Purdue Research Foundation–David Ross Grant.
(*c*) D. P. Kessler, Assoc. Professor.
(*d*) Experimental, theoretical, basic; M. S. and Ph.D. theses.
(*e*) In a horizontal pipe, two potentially useful flow regimes for mass transfer are dispersed flow, essentially a spray, and annular flow, a gas phase or spray surrounded by a turbulent annular liquid film. The degree of turbulence and interfacial area are large. Present work is in the area of physical measurement of interfacial area, holdup, and drop size distribution. Drop velocities in the radial direction have been measured photographically as a function of positions in the pipe. A numerical calculation of droplet transfer is being developed.
(*h*) **Mass Transfer in Horizontal Cocurrent Annular Flow,** R. L. Davison, D. P. Kessler, presented at *66th Natl. AIChE Mtg.*, Portland, Oreg., Aug. 1969.
Mass Transfer in Horizontal Cocurrent Annular Flow, R. L. Davison, *M. S. Thesis*, available Purdue Univ. Library.
Hydrodynamics of Horizontal Annular Cocurrent Flow, R. L. Davison, *Ph.D. Thesis*, available Purdue Univ. Library.

148-08241-130-54

TURBULENT MOTIONS IN THE IMMEDIATE VICINITY OF A GAS-LIQUID INTERFACE

(*b*) National Science Foundation–Research Initiation Grant.
(*c*) R. N. Houze, Asst. Professor.
(*d*) Experimental, theoretical, basic; M. S. and Ph.D. theses.
(*e*) Initial phase of experimental program to study the nature of unsteady motions near a structured, gas-liquid interface. Recently developed experimental techniques are being employed with digital data analysis.

148-08242-020-00

STATISTICAL AND PHENOMENOLOGICAL MODELS OF TURBULENT ENERGY EQUATION

(*c*) R. N. Houze, Asst. Professor.
(*d*) Theoretical; basic.
(*e*) Solutions of the turbulent energy equation are being obtained utilizing various statistical and phenomenological models for the turbulent stresses. Solutions are being compared with available published data. Methods are to be extended to free surface flows, with aim of predicting turbulence characteristics pertinent to interphase transport processes.

148-08243-130-00

FREE BOUNDARY TURBULENCE

(*b*) Purdue Research Foundation–David Ross Grant.
(*c*) Asst. Professors R. N. Houze, T. G. Theofanous.
(*d*) Experimental, theoretical, basic; M. S. and Ph.D. theses.
(*e*) A two-dimensional fully developed, stratified, gas liquid flow system is being studied with special emphasis on the turbulent characteristics of the liquid phase in the immediate vicinity of the interface.

148-08244-130-00

TURBULENT TRANSPORT AT FREE INTERFACES

(*b*) Purdue Research Foundation–David Ross Grant.
(*c*) Asst. Professors R. N. House, T. G. Theofanous.
(*d*) Experimental, theoretical, basic; Ph.D. theses.
(*e*) Statistical and eddy turbulence models are being devised to elucidate the mechanism of the fluid mechanical interaction of bulk turbulence and a free interface and hence arrive to a quantitative description of the mass transfer characteristics of the interface.
(*h*) **On Predicting Mass Transfer at Turbulent Free Interfaces With a Large Eddy Model,** L. K. Brumfield, *M. S. Thesis*, available Purdue Univ. Library.

148-08245-120-00

RHEOLOGICAL PROPERTIES OF VISCOELASTIC POLYMERS

(*b*) Purdue Research Foundation.
(*c*) Roger E. Eckert, Assoc. Professor.
(*d*) Experimental, theoretical, basic; M. S. and Ph.D. theses.
(*e*) Obtain fundamental properties of viscoelastic polymers through the industrially and fundamentally important high shear rate regions. These basic rheological properties are evaluated throughout a very wide range of shear rates by studying continuous flow through a channel approximating

infinite parallel plates. This seldom explored geometry for the flow channel has now been found to have important advantages in obtaining both shear and normal stress measurements. Pressure transducers are flush mounted at various distances down the channel to measure the force exerted by the fluid. The shear stress and the normal stress perpendicular to the plates are measured as functions of shear rate. This geometry enables us to measure the shear stress and the normal stress perpendicular to the plates at shear rates from 0.03 to 25,000 sec^{-1}, the upper value being limited only by the onset of turbulence in the particular dimensions used. Thrust measurements on the exiting fluid stream are taken to determine the normal stress in the direction of flow; it can be measured in a higher range of shear rate, 40,000 to 130,000 sec^{-1}. By combining these parallel plate data with measurements obtained on our Weissenberg Rheogoniometer this normal stress can also be extended to lower shear rates.

(*h*) **Normal and Shear Stress Measurement in Flow Between Parallel Flat Plates,** E. J. Novotny, Jr., *M. S. Thesis*, available Purdue Univ. Library.

PURDUE UNIVERSITY, Department of Geosciences, Lafayette, Ind. 47907. Dr. William L. Wood, Associate Professor.

150-08606-410-20

WAVE AND CURRENT ENERGY IN THE NEARSHORE ZONE

(*b*) Geography Programs, Office of Naval Research.
(*d*) Theoretical and field investigation, basic.
(*e*) Research is designed to evaluate wave induced energy parameters from the surf zone shoreward and the interaction of bathymetry, currents, and waves.
(*g*) Turbulent dissipation coefficients for the decay of breaking wave heights have been established for a barred configuration. Flow profiles beneath the crests of breaking waves have been related to wave shape criteria for momentum analysis.
(*h*) **A Ducted Impeller Flowmeter for Shallow-Water Measurements of Internal Velocities in Breaking Waves,** W. L. Wood, *Tech. Rept. No. 1*, Dept. of Geology, Mich. State Univ., 1968.
A Shallow-Water Instrument System for Monitoring Wave and Current Parameters in the Nearshore Zone, W. L. Wood, *Tech. Rept. No. 2*, Dept. of Geology, Mich. State Univ., 1970.
Horizontal Particle Velocity Profiles Beneath the Crests of Waves Breaking on a Submarine Bar, W. L. Wood, *Tech. Rept. No. 3*, Dept. of Geology, Mich. State Univ., 1970.
Transformations of Breaking Wave Characteristics over a Submarine Bar, W. L. Wood, *Tech. Rept. No. 4*, Dept. of Geology, Mich. State Univ., 1970.

150-08607-440-00

DYNAMICS OF RIP CELLS IN THE GREAT LAKES

(*d*) Field investigation and theoretical, basic.
(*e*) Research is being conducted on the presence and dynamic conditions surrounding the existence of rip cells in the Great Lakes. Current activities are centered on the eastern shore of Lake Michigan.

PURDUE UNIVERSITY, School of Mechanical Engineering, Lafayette, Ind. 47907. Professor W. B. Cottingham, Head, School of Mech. Engrg., Professor R. Cohen, Director, Ray W. Herrick Laboratories.

151-05741-000-00

A STUDY OF ROTATING FLUIDS BETWEEN PARALLEL DISKS

(*c*) Dr. E. J. Wellman, Assoc. Professor.
(*d*) Analytical and experimental; basic research for Doctoral thesis.
(*e*) The system consists of an 18-inch diameter vertical cylindrical tank within which a rotating coaxial circular disk is mounted parallel to the bottom of the tank. Disks of several sizes have been operated at a series of speeds and spacings with the disk rotating in contact with a water surface. Extensive velocity measurements have been made using hydrogen bubbles. Many photographs have been taken of the multiple vortex patterns generated using pearl essence solutions for visualization. The data is presently being analyzed in an effort to develop prediction methods for the flow patterns observed. The study should have application to rotating fluid machinery and also to atmospheric flow conditions.
(*g*) Stable, rotating, symmetrical vortices have been photographed under various flow conditions with the number of vortices ranging from three to more than thirty. The number of vortices is related to the disk spacing and the Reynolds number. The velocities measured in the vortex-free flow at the lower Reynolds numbers are in good agreement with those obtained from numerical solutions of the equations of motion.
(*h*) **Instability Phenomenon Associated with an Enclosed Rotating Disk,** J. P. Macey, E. J. Wellman, *Physics of Fluids* **12,** 3, pp. 720-722, Mar. 1969.

151-07602-130-54

TURBULENT DIFFUSION OF SMALL CONTAMINANTS

(*b*) National Science Foundation; Environmental Protection Agency.
(*c*) V. W. Goldschmidt, Assoc. Professor.
(*d*) Experimental and theoretical; Master's and Doctoral theses.
(*e*) To evaluate the turbulent transport of contaminants carried by turbulent streams.
(*f*) Completed.
(*g*) The dispersion of drops in air jets and bubbles in liquid jets, both circular and plane has been measured. The turbulent Schmidt number decreases with suspended particle response time.
(*h*) **Analytical Prediction of the Turbulent Diffusion of Small Solid Particles,** *Fluid Dynamics Symp.*, Hamilton, Canada, Aug. 1970 (co-authored).
Dynamic Simulation of the Turbulent Diffusion of Small Particles, *Proc. 1st Intl. Conf. on Hydraulic Transport of Solids in Pipes* (*Hydrotransport 1*), British Hydromech. Res. Assoc., Cranfield, Sept. 1970 (co-authored), pp. F5-57 to F5-68.
Bubble Formation Due to a Submerged Capillary Tube in Quiescent and Coflowing Streams, *J. Basic Engrg., Trans. ASME* **92,** Series E, 4, Dec. 1970 (co-authored), pp. 705-711.
Distribution of Mass, Velocity and Intensity of Turbulence in a Two-Phase Turbulent Jet, a discussion on the paper by G. Hetsroni and M. Sokolov, *J. Appl. Mech., Trans. ASME* **38,** Series E, 2, June 1971, pp. 568-569.
Motion of Particles in a Turbulent Fluid–The Basset History Term, *J. Appl. Mech., Trans. ASME* **38,** Series E, 2, June 1971 (co-authored), pp. 568-569.
Creation of a Pseudo-Turbulent Velocity Field, *Developments in Mechanics* **6,** *Proc. 12th Midwestern Mechanics Conf.*, Aug. 1971 (co-authored), pp. 291-304.
Turbulent Diffusion of Small Particles Suspended in Turbulent Jets, *Paper 4-2*, *Intl. Symp. on Two-Phase Systems*, Technion, Aug.-Sept. 1971 (co-authored).

151-08255-050-54

TURBULENT TRANSPORT IN JETS

(*b*) National Science Foundation.
(*c*) V. W. Goldschmidt, Assoc. Professor.
(*d*) Primarily experimental; Master's and Doctoral theses.
(*e*) Purpose is twofold. One, to determine further investigations of the seemingly faster transport of heat than of momentum in jet flows; secondly, to measure both the magnitude and sense of the convected velocities of turbulent patterns.
(*h*) **Interaction of an Acoustic Field and a Turbulent Plane Jet; Mean Flow Measurements,** *AIChE Chem. Engrg. Symp. Series* 67, 109, 1971 (co-authored), pp. 91-98.
Energy Spectrum and Turbulent Scales in a Circular Water Jet, *Paper 71-WA-FE-4*, 1971.

151-08256-290-00

ACOUSTIC EFFECTS ON THE GROWTH RATE OF GREEN PLANTS

(*c*) V. W. Goldschmidt, Assoc. Professor.
(*d*) Experimental project leading to a Doctoral thesis.
(*e*) The frequency intensity of an acoustic signal at which green plants have an enhanced growth rate is to be determined.
(*g*) The water uptake rate appears to increase with signal intensity whereas the growth rate seems to increase when the disturbing source is first turned on.

THE RAND CORPORATION, Department of Physical Sciences, 1700 Main Street, Santa Monica, Calif. 90406. Dr. R. M. Salter, Department Head. (Publications may be purchased.)

152-06790-480-18

CLOUD DYNAMICS AND CLOUD PHYSICS

(*b*) ARPA, Navy Environmental Prediction Research Facility, NOAA Experimental Meteorology Laboratory.
(*c*) F. W. Murray.
(*d*) Theoretical.
(*e*) With the ultimate objective of providing inputs for an atmospheric model for weather modification studies, this is an attempt to develop a computer model of a cumulus cloud that follows the growth from the start of convection. Other basic studies include the microphysical effects of cloud-droplet coalescence and other processes.
(*g*) Parameterized microphysics of liquid processes has been incorporated into a hydrodynamical model, and processes involving ice crystals are now being included. The relative importance to cloud growth and decay of various processes has been clarified.
(*h*) **Parameterization of Ice Growth for Numerical Calculations of Cloud Dynamics,** L. R. Koenig, *R-846-NOAA*, 25 pp., July 1971.
Numerical Experiments on the Relation Between Microphysics and Dynamics in Cumulus Convection, F. W. Murray, L. R. Koenig, *R-852-ARPA*, 43 pp., Aug. 1971.
Calculation of the Terminal Velocity of Water Drops, H. B. Wobus, F. W. Murray, L. R. Koenig, *P-4564*, 12 pp., Jan. 1971.

152-06793-270-40

FLUID MECHANICS OF THE HUMAN MICROCIRCULATION

(*b*) National Institutes of Health.
(*c*) Dr. Carl Gazley, Jr.
(*d*) Theoretical; applied research.
(*e*) Study of the fluid mechanics of the human microcirculation. Development of analytical and numerical models of the flow and diffusional transport in the small vessels of a microcirculatory network. Current emphasis is on the effects of non-Newtonian and pulsatile-flow aspects.
(*g*) Analytic models have been developed of plasma motion and mass transfer between red cells in a capillary, non-Newtonian flow in an arteriole, and pulsatile non-Newtonian flow in a microcirculation network.
(*h*) **Convection and Diffusion in the Microcirculation,** J. Aroesty, J. F. Gross, *RM-6214-NIH*, 43 pp., May 1970.
Pulsatile Flow in Small Blood Vessels. I. Casson Theory, J. Aroesty, J. F. Gross, *R-767-NIH*, 21 pp., Apr. 1971.
The Mathematics of Pulsatile Flow in Small Vessels. I. Casson Theory, J. Aroesty, J. F. Gross, *R-768-NIH*, 23 pp., Apr. 1971.
Rheological Properties of Biological Flow Systems, C. Gazley, Jr., *R-769-NIH*, 33 pp., Apr. 1971.
Mathematical Models of Capillary Flow: A Critical Review, J. F. Gross, J. Aroesty, *R-959-NIH*, 78 pp. (in process of publication).
On Pulsatile, Non-Newtonian Flow in the Microcirculation, J. Aroesty, C. Gazley, Jr., J. Gross, *P-4516*, 10 pp., Dec. 1970.
Pulsatile Flow in the Microvessels, J. Aroesty, J. F. Gross, C. Gazley, Jr., *P-4636*, 24 pp., Apr. 1971.
Small-Scale Phenomena in the Flow of Dispersion, C. Gazley, Jr., *P-4796, 25 pp., Mar. 1972.*
The Fluid Mechanics of Pulsatile Flow in the Microcirculation, J. F. Gross, J. Aroesty, *P-4785*, 12 pp., Mar. 1972.

152-06795-860-65

DEVELOPMENT OF WATER QUALITY SIMULATION MODEL

(*b*) City of New York.
(*c*) J. J. Leendertse.
(*d*) Applied.
(*e*) To develop a computational model for the flow in estuaries and coastal seas, combined with a model for the advective and diffusive transport of pollutants, which also permits simulation of reactions of pollution substances.
(*g*) The model for the flow and the advective and diffusive transport of pollutants in well-mixed waters has been developed and is being evaluated for Jamaica Bay, New York. The two-dimensional model includes flow over tidal flats which may become exposed during ebb. Results are presented in graphs and charts with isocontours of concentrations. The model is being used in support of the extent and control of pollutants in the Bay.
(*h*) **A Water-Quality Simulation Model for Well-Mixed Estuaries and Coastal Seas: Vol. I, Principles of Computation,** J. J. Leendertse, *RM-6230-RC*, Feb. 1970.
A Water-Quality Simulation Model for Well-Mixed Estuaries and Coastal Seas: Vol. II. Computation Procedures, J. J. Leendertse, E. C. Gritton, *R-708-NYC*, 53 pp., July 1971.
A Water-Quality Simulation Model for Well-Mixed Estuaries and Coastal Seas: Vol. III, Jamaica Bay Simulation, J. J. Leendertse, E. C. Gritton, *R-709-NYC*, 73 pp., July 1971.
A Water-Quality Simulation Model for Well-Mixed Estuaries and Coastal Seas: Vol. IV. Jamaica Bay Tidal Flows, J. J. Leendertse, *R-1009-NYC* (in process of publication).
A Water-Quality Simulation Model for Well-Mixed Estuaries and Coastal Seas: Vol. V. Jamaica Bay Rainstorms, E. C. Gritton, *R-1010-NYC* (in process of publication).
The Use of Water-Quality Simulation Models in the Analysis of the Thermal Effects Problem, E. C. Gritton, J. S. Kvitky, J. J. Leendertse, *P-4772*, 5 pp., Feb. 1972.

152-08257-030-18

LAMINAR WAKE PHENOMENA

(*b*) Advanced Research Projects Agency.
(*c*) Dr. J. F. Gross.
(*d*) Theoretical, applied research.
(*e*) Survey and analysis of laminar wake phenomena, emphasizing recent supersonic and hypersonic wake

research. To organize and review this information for application to problems associated with atmospheric re-entry.
(*f*) Completed.
(*g*) Comprehensive survey of present state of knowledge of laminar wakes (see below).
(*h*) **Laminar Wakes,** Stanley A. Berger, American Elsevier, New York, 1971, 294 pp. (or *R-467-ARPA/ONR*, The Rand Corporation).

152-08258-480-18

CLIMATE DYNAMICS

(*b*) Advanced Research Projects Agency, Department of Defense.
(*c*) R. R. Rapp.
(*d*) Theoretical and numerical; basic and applied.
(*e*) Documentation, calibration, and application of numerical models of the general atmospheric circulation. The design, execution, and evaluation of selected numerical experiments on the sensitivity and stability of the global climate to specific perturbations in the model's initial and/or boundary conditions. Model's physics includes atmospheric and ground radiation balance, the hydrological cycle including precipitation, ground wetness, and runoff. Also under development is an ocean model to permit the simulation of the joint ocean-atmosphere system.
(*g*) A complete documentation of the Mintz-Arakawa atmospheric model has been produced, a collection of observed global climatological fields started, and the model's simulation of the January climate evaluated. Numerical experiments for as long as 60 days simulated time have been performed to examine the climatic effects of the removal of the Arctic sea ice, the warming of the North Pacific Ocean, and the scattering of solar radiation outside the earth's atmosphere. Tests have also been conducted to determine the effects of random initial uncertainties. These experiments are being summarized and further are planned. Simple barotropic and two-layer baroclinic ocean models are undergoing testing in idealized basins as a prelude to their application to the world ocean.
(*h*) **A Documentation of the Mintz-Arakawa Two-Level Atmospheric General Circulation Model,** W. L. Gates, E. S. Batten, A. B. Kahle, A. B. Nelson, *R-877-ARPA*, 406 pp., Dec. 1971.
Studies in Climate Dynamics for Environmental Security: A Note on the Lateral Eddy Viscosity Due to Transient Rossby Waves in a Barotropic Ocean Model, W. L. Gates, *RM-6210-ARPA*, 12 pp., Feb. 1970.
Studies in Climate Dynamics for Environmental Security: Numerical Studies of Transient Planetary Circulations in a Wind-Driven Ocean on the Sphere, W. L. Gates, *RM-6211-ARPA*, 53 pp., Mar. 1970.
Studies in Climate Dynamics for Environmental Security: A Calibrated Analytical Model for the Thermohaline and Wind-Driven Circulation in the Interior of a Subtropical Ocean, R. C. Alexander, *R-505-ARPA*, 26 pp., Sept. 1970.
An Experiment on the Sensitivity of a Global Circulation Model: Studies in Climate Dynamics for Environmental Security, M. Warshaw, R. R. Rapp, *R-908-ARPA*, 26 pp., Jan. 1972.
Global Climatic Data for Surface, 800 mb, 400 mb: January, C. Schutz, W. L. Gates, *R-915-ARPA*, 181 pp., Nov. 1971.
Analysis of the Mean Forcing Fields Simulated by the Two-Level Mintz-Arakawa Atmospheric Model, W. L. Gates, *R-958-ARPA*, 43 pp., Apr. 1972.
Global Climatic Data for Surface, 800 mb, 400 mb: July, C. Schutz, W. L. Gates, *R-1029-ARPA* (in process of publication).

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RENSSELAER POLYTECHNIC INSTITUTE, Department of Mathematics, Troy, N.Y. 12181. Dr. George H. Handelman, Department Chairman.

153-06772-000-20

STABILITY OF VISCOUS FLOW OVER CURVED SURFACES

(*b*) Office of Naval Research.
(*c*) Professors R. C. DiPrima, L. A. Segel.
(*d*) Theoretical; basic research.
(*e*) Stability and two-phase effects are studied in an effort to achieve basic understanding of fluid flows which have importance in applications.
(*g*) Several investigations have been made of fundamental nonlinear effects in hydrodynamic stability. Azimuthal effects have been considered in a major linear stability theory calculation for eccentric cylinders. The work has importance for stability theory generally for classes of flows which vary in the direction of the flow, and for the lubrication of lightly loaded journal bearings in particular. A general averaging approach to two-phase flows has been applied to fluidized beds and foams. Also see 153-06773.
(*h*) **Stability of Spatially Periodic Supercritical Flows in Hydrodynamics,** S. Kogelman, R. C. DiPrima, *Phys. Fluids* **13**, 1-11, 1970.
Nonlinear Wave-Number Interaction in Near-Critical Two-Dimensional Flows, R. C. DiPrima, W. Eckhaus, L. A. Segel, *J. Fluid Mech.* **49**, 705-44, 1971.
Averaged Equations for Two-Phase Flows, D. Drew, L. A. Segel, *Studies in Appl. Math. L*, 205-232, 1971.
Analysis of Fluidized Beds and Foams Using Averaged Equations, D. Drew, L. A. Segel, *Studies in Appl. Math. L*, 233-258, 1971.
Flow Between Eccentric Rotating Cylinders, R. C. DiPrima, J. T. Stuart, to appear in *J. Lub. Tech.*
Non-Local Effects in the Stability of Flow Between Eccentric Rotating Cylinders, To appear in *J. Fluid Mechanics.*
Simplification and Scaling, L. A. Segel, to appear in *SIAM Review.*

153-06773-000-14

NONLINEAR EFFECTS IN HYDRODYNAMIC AND THERMAL INSTABILITY PROBLEMS

(*b*) U.S. Army Research Office–Durham.
(*c*) Professors R. C. DiPrima, L. A. Segel.
(*d*) Theoretical; basic research.
(*e*) Nonlinear stability theory and formal averaging techniques are applied to the study of flow processes. Singular perturbation theory has been applied to problems in gas bearing lubrication theory.
(*g*) For a class of fluid stability problems, investigation has been made of the interaction of flow modes having many different near-critical wave-numbers. New basic differences between Taylor-Bnard and parallel-flow type instability problems have been revealed. An averaging approach has been formulated which provides a framework for the investigation of two-phase systems. Also see 153-06772.
(*h*) **Nonlinear Wave-Number Interaction in Near-Critical Two-Dimensional Flows,** R. C. DiPrima, W. Eckhaus, L. A. Segel, *J. Fluid Mech.* **49**, 705-44, 1971.
Averaged Field Equations for Two-phase Media, *Studies in Applied Mathematics L*, 133-166 (1971).
Existence, Uniqueness, and Asymptotic Representation for Large Bearing Numbers of the Solution of the Nonlinear Reynolds Equation of Gas Bearing Theory, W. Steinmetz, *Ph.D. Dissertation*, Dept. of Mathematics, Rensselaer Poly. Inst., 1970.
A Linear Stability Analysis of a Two-Dimensional Fluid Flow in a Constantly Rotating System, R. Wollkind, *Ph.D. Dissertation*, Dept. of Mathematics, Rensselaer Poly. Inst., 1970.

517-020 O-LT - 74 - 8

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UNIVERSITY OF RHODE ISLAND, Graduate School of Oceanography, Narragansett Marine Laboratory, Kingston, R.I. 02881. Dr. John A. Knauss, Dean of School.

154-06220-420-48

INTERNAL WAVES AND TURBULENCE

(*b*) U.S. Coast Guard Oceanographic Unit.
(*c*) Dr. Kern Kenyon, Narragansett Marine Lab., and Dr. John E. Spence, Dept. of Ocean Engineering.
(*d*) Theoretical and field investigation; basic research for M.S. thesis.
(*e*) To measure and explain coherence of temperature records obtained from vertically separated sensors in shallow ocean depths.
(*f*) Completed.
(*g*) For a given frequency the coherence between two temperature records is observed to decrease with increasing vertical separation, and for a given vertical separation the coherence decreases with increasing frequency. Attempts to explain these observations in terms of simple theories have met with limited success.
(*h*) **Report on Oceanographic Data Analysis and Interpretation and the Evaluation of Existing and Proposed Oceanographic Data Systems–II,** C. Beckers, A. Bhopale, J. Osuna, J. E. Spence, *Tech. Rept. Div. of Engrg. Research and Development*, Univ. of Rhode Island, Feb. 1970.

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ROCKY MOUNTAIN HYDRAULIC LABORATORY, Allenspark, Colo. 80510. Professor C. J. Posey, Director. (Winter Address; Dept. of Civil Engrg., U. Of Connecticut, Storrs, Conn. 06268).

155-06377-220-61

HOW TO PLACE ROCK SAUSAGES TO OBTAIN EFFECTIVE EROSION PROOFING

(*b*) Water Resources Inst., Univ. of Connecticut.
(*d*) Experimental; development or applied research.
(*e*) This phase of a Water Resources Institute project was undertaken to develop criteria for fail-safe installation of rock sausages.
(*f*) Completed except for formulation of specifications and standards that should attract bids competitive with other methods of erosion protection. Ecological effects of large installations will need study.
(*h*) **Erosion Protection,** 30-minute 16 mm silent color film, available at $1.00 rental charge from Audiovisual Dept., U. of Conn., Storrs, Conn. 06268.

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RUTGERS UNIVERSITY, The State University of New Jersey, College of Engineering, Department of Mechanical, Industrial and Aerospace Engineering, New Brunswick, N.J. 08903. Dr. R. H. Page, Department Chairman.

156-07613-000-54

STABILITY OF TIME-DEPENDENT ROTATIONAL FLOW

(*b*) National Science Foundation.
(*c*) Professor C. F. Chen.
(*d*) Experimental and theoretical; basic research; Ph.D. thesis.
(*e*) To study both experimentally and theoretically the stability of a basically time-dependent flow. To accomplish the objective simply and with some degree of accuracy, a rotating Couette flow is studied.
(*g*) For a Couette flow with a radius ratio of 0.1, the critical time for the onset of instabilities has been determined experimentally. A quasi-steady, linear perturbation analysis has been applied to predict the critical time with qualified success. Theoretical analyses are underway to use the initial value approach to the problem, and to numerically integrate the Navier-Stokes equation for the flow region to detect the onset of instability.
(*h*) **The Stability of Viscous Time-Dependent Flow Between Concentric Rotating Cylinders with a Wide-Gap,** R. P. Kirchner, *Ph.D. Thesis*, Dept. of Mech. and Aerospace Engrg., Rutgers Univ., Oct. 1968.
The Stability of Time-Dependent Rotational Couette Flow. Part I. Experimental Investigation, R. P. Kirchner, C. F. Chen, *J. Fluid Mech.* **40,** 1, pp. 39-48, Jan. 1970.

156-07614-030-26

NUMERICAL METHODS FOR FREE SHEAR LAYER PROBLEMS

(*b*) Air Force Office of Scientific Research.
(*c*) Professor R. H. Page.
(*d*) Theoretical; applied research.
(*e*) Numerical solutions of laminar and turbulent flows associated with wakes and base flow problems are obtained by finite difference methods. Coordinate transformations which lead to computationally efficient schemes are being investigated.
(*f*) Completed.
(*g*) A linear multi-level finite difference scheme has been applied to solve free mixing flow problems.
(*h*) **An Examination of Eddy Viscosity Models for Turbulent Free Shear Flows,** R. J. Elassar, P. P. Pandolfini, *ASME Paper 71-FE-17*, May 1971.

156-07616-000-26

SEPARATED FLOWS

(*b*) Air Force Office of Scientific Research.
(*c*) Professor R. H. Page.
(*d*) Experimental and theoretical basic research.
(*e*) Basic research in separated flows is being carried out to determine a much more fundamental understanding of the thermodynamic and dynamic mechanisms.
(*f*) Completed.
(*g*) Special experimental research facilities have been developed and theoretical models of various separated or separating flows have been formulated.
(*h*) **Separated Flows–Final Scientific Report,** R. H. Page, *AFOSR-TR-71-2325*, available from DDC.

156-07618-720-80

EMIL BUEHLER WIND TUNNEL

(*b*) Emil Buehler Foundation.
(*c*) Professor R. H. Page.
(*d*) Design; development.
(*e*) Design, operation, and development, of a supersonic variable Mach number wind tunnel and auxiliary apparatus for teaching and research programs. A variable Mach number wind tunnel (up to Mach 4.0) has been used extensively since it was first operated on April 21, 1964. It is used for teaching and research programs.
(*g*) Improvements in the tunnel's operation have been continuously made.
(*h*) **The Theory and Operation of the Emil Buehler Supersonic Wind Tunnel,** C. P. Sarkos, *Master's Thesis*, Rutgers Univ., June 1965.

156-07619-600-00

FLUIDICS RESEARCH

(*c*) Professor R. H. Page.
(*d*) Theoretical and experimental investigations.
(*e*) Theoretical analyses of separating and reattaching flows are being cariied out and verified with specially designed experiments.
(*g*) Basic fluid mechanics of supersonic separation and reattachment for fluidic devices has been formulated.
(*h*) **Fluid Mechanics of Supersonic Separation and Reattachment,** R. H. Page, *Proc., IFAC Symp. on Fluidics*, London, Nov. 1968.

156-07621-030-26

THE TURBULENT WAKE OF AN AXISYMMETRIC BODY AT SUBSONIC SPEEDS

(*b*) Air Force Office of Scientific Research.
(*c*) Associate Professor C. E. G. Przirembel.
(*d*) Experimental, theoretical; basic research.
(*e*) The near-wake of an axisymmetric body, which is immersed in a uniform subsonic flow field, is under extensive experimental and theoretical investigation. The present experimental model is a circular cylinder aligned with the free stream direction. The base of the model is blunt, so that the separation line of the approaching boundary layer is fixed at a known location. Fundamental understanding of this near-wake flow field is necessary for the prediction of base drag, base heat transfer, and the configuration of the related far wake. For example, this type of flow field is associated with the motion of such diverse objects as missiles, aircraft, buses, and flowmeter elements.
(*f*) Completed.
(*g*) A special low turbulence wind tunnel with a closed jet test section is being used for the experimental program. The model support system has been designed to eliminate any support interference effects on the free stream and the approaching boundary layer. Detailed pressure measurements were made in all regions of the near-wake, as well as in the approaching flow and on the body surface. The flow field was found to be quite insensitive to changes in the free stream Mach number ($0.14 \leq M\infty \leq 0.30$) with respect to the base pressure coefficient and the location of the rear stagnation point. The influence of the separation processes was found to extend approximately two base diameters upstream on the body. The dividing streamline was nearly elliptical in shape. Extensive comparison of the present data and that of other authors with the two available subsonic wake theories showed reasonable agreement for the base pressure but substantial scatter for the length of the recirculation region.
(*h*) **The Turbulent Near-Wake of an Axisymmetric Body at Subsonic Speeds,** D. P. McErlean, C. E. G. Przirembel, *RU-TR 132-MAE-F*, Dept. of Mech. and Aerospace Engrg., Rutgers Univ., Feb. 1970.
An Experimental Study of the Subsonic Turbulent Boundary Layer Approaching an Axisymmetric Blunt Base, C. H. Yi, *M. Phil. Thesis*, Apr. 1970.

156-08259-020-54

TURBULENCE AND TURBULENT DIFFUSION IN STRATIFIED FLOW

(*b*) National Science Foundation.
(*c*) Professor Richard L. Peskin.
(*d*) Theoretical and experimental research.
(*e*) To study the structure of turbulence in stratified flow with particular application of the atmospheric boundary layer. The Langevin theory for turbulent diffusion is being modified to be applicable to problems in stratified turbulent flow. This theory is of interest in estimation of turbulent diffusion. Three-dimensional numerical simulation of the channel flow is being revised and boundary conditions appropriately changed to effect simulation of the atmospheric boundary layer. Data tapes from the Bomex experiment are being analyzed to obtain more information on microstructure and dissipation rates in stratified turbulence and a wind tunnel experiment is being performed to investigate the approach to isotropy and the effect of stratification on this approach.
(*h*) **The Langevin Model for Turbulent Diffusion,** Krasnoff and Peskin, *Geophysical Flyid Dynamics*, 1971.

156-08260-130-54

INVESTIGATION OF GAS-PARTICLE SHEAR FLOWS

(*b*) National Science Foundation.
(*c*) Professor R. L. Peskin.
(*d*) Theoretical and experimental applied research.
(*e*) To investigate three-dimensional shear flows. Theoretical study using a new stochastic estimation model was undertaken to study both the Eulerian-Lagrangian problem and the application of Eulerian-Lagrangian relation to diffusion. The same stochastic estimation model was also used to study finite particle motion in turbulent flow. Analytical results include prediction of effective Schmidt number ratios, that is, the ratio of particle diffusivity to eddy diffusivity of turbulence. A numerical simulation of channel flow was developed involving over 10,000 grid points. This three-dimensional simulation was used to study the Eulerian structure of channel flow, the Lagrangian structure of such flows, and the motion of particles in turbulent shear flow. Among the various results obtained were numerically predicted particle Schmidt numbers. It was shown that the Schmidt number depends in large measure on the nature of shear flow and that the presence of shear has a larger effect on fluid points than on solid particles. Of significance was the test of the Corrsin hypothesis between Lagrangian correlation and Eulerian space-time correlation. Experimentally, a laser-Doppler anemometer has been developed to study the finite particles in a turbulent flow. This highly accurate system enables investigation of particle velocity statistics in the shear flow and is capable of extension to obtain both gas turbulence and particle fluctuation information simultaneously.
(*h*) **Lagrangian Statistics from Numerically Integrated Turbulent Shear Flow,** Peskin and Deardorff, *Phys. Fluids* **13**, 3, p. 584, Mar. 1970.
The Langevin Model for Turbulent Diffusion, Peskin and Krasnoff, *Geophys. Fluid Dyn.*, 1971.
Stochastic Estimation Applications to Turbulent Diffusion, R. L. Peskin, *Proc. Intl. Symp. Stochastic Hydraulics*, U. of Pittsburgh, 1971.
Numerical Simulation of Turbulence and Diffusion in Three-Dimensional Flow, Kau and Peskin, Mar. 1972.

156-08261-060-54

STUDIES IN THERMOHALINE CONVECTION

(*b*) National Science Foundation.
(*c*) Professor C. F. Chen.
(*d*) Experimental and theoretical; basic research.
(*e*) To investigate possible mechanisms for the genesis and maintenance of microstructures found in many parts of the world's ocean. Specifically, we study the onset of horizontal cellular convection in a stratified fluid due to an imposed horizontal temperature gradient.
(*g*) The critical value of Rayleigh number above which cellular convection appears has been determined experimentally to be 1.5×10^4. This result has been corroborated by a nonlinear numerical experiment and by a linear stability analysis.
(*h*) **Stability of Thermal Convection in a Salinity Gradient Due to Lateral Heating,** C. F. Chen, D. G. Briggs, R. A. Wirtz, *Int. J. Heat Mass Transf.* **14**, pp. 57-65, 1971.
Physical and Numerical Experiments of Cellular Convection in a Stratified Fluid Due to Lateral Heating, R. A. Wirtz, *Ph.D. Thesis*, Dept. of Mechanical and Aerospace Engrg., Rutgers Univ., Jan. 1971.
Physical and Numerical Experiments on Layered Convection in a Density Stratified Fluid, R. A. Wirtz, D. G. Briggs, C. F. Chen, *Geophys. Fluid Dynamics* **3**, 1972.
Cellular Convection in a Stratified Fluid Due to Imposed Lateral Temperature Gradient, C. F. Chen, *Proc. 4th Colloq. Hydrodynamics of the Ocean*, Liege University, Belgium, Mar. 1972.
Onset of Cellular Convection in a Stratified Fluid Due to Lateral Temperature Gradient, C. F. Chen, presented at *XIII Intl. Congr. Theoret. and Appl. Mech.*, Moscow, Aug. 1972.

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ST. ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA, Mississippi river at Third Avenue, S. E., Minneapolis, Minn. 55414. Dr. Edward Silberman, Director.

Inquiries concerning Projects 0166W, 0167W, 0168W, 0169W, 0170W, 0171W, 0172W, 05500, 05795, 06735, 06744, 07661, 07662, 07673, 08289 through 08306, should be addressed to the Director, St. Anthony Falls Hydraulic Laboratory, at the above address.

Inquiries concerning Projects 00111, 07677, which are conducted by the Agricultural Research Service, should be addressed to Mr. Fred W. Blaisdell, Research Investigations Leader, Soil and Water Conservation Research Division, Agricultural Research Service, St. Anthony Falls Hydraulic Laboratory, at the above address.

Inquiries concerning Project 00194, which is conducted in cooperation with the Corps of Engineers and the U.S. Geological Survey, should be addressed to Engineer in Charge, Mr. John V. Skinner, Federal Inter-Agency Sedimentation Project, St. Anthony Falls Hydraulic Laboratory, at the above address.

157-0166W-320-00

DESIGN OF EROSION RESISTANT CHANNELS

For summary, see Water Resources Research Catalog **6**, 8.0342.

157-0167W-360-00

SCALING LAWS ASSOCIATED WITH PRESSURE FLUCTUATION IN THE VICINITY OF A HYDRAULIC JUMP

For summary, see Water Resources Research Catalog **6**, 8.0345.

157-0168W-360-00

A STUDY OF A MULTIPLE-JET CONTROL AND DISSIPATION SYSTEM FOR HIGH HEAD HYDRAULIC STRUCTURES

For summary, see Water Resources Research Catalog **6**, 8.0346.

157-0169W-720-00

CONTROLLED TEMPERATURE REGIMES IN OUTDOOR EXPERIMENTAL PONDS

For summary, see Water Resources Research Catalog **6**, 5.0758.

157-0170W-340-00

MODEL STUDY OF INTAKE AND DISCHARGE STRUCTURES FOR ZION NUCLEAR STATION

For summary, see Water Resources Research Catalog **6**, 8.0348.

157-0171W-810-00

EVALUATION OF SELECTED COMPUTER PROGRAMS IN HYDROLOGY

For summary, see Water Resources Research Catalog **6**, 2.0904.

157-0172W-810-00

MATHEMATICAL WATERSHED SIMULATION USING SYSTEMS APPROACH

For summary, see Water Resources Research Catalog **6**, 6.0516.

157-00111-350-05

CLOSED CONDUIT SPILLWAY

(*b*) Agricultural Research Service, U.S. Dept. of Agric., in cooperation with the Minnesota Agric. Expt. Sta. and the St. Anthony Falls Hydraulic Laboratory.
(*d*) Experimental; generalized applied research for development and design.
(*e*) A square drop inlet having a hood barrel entrance is being tested to determine entrance loss coefficients for various drop inlet sizes and heights and various barrel slopes. Previous tests have evaluated the performance of this type of inlet. The elbow and transition between the two-way drop inlet and the barrel is being studied to determine the pressures and the best form to minimize the possibility of cavitation.
(*g*) The theory of closed conduit spillways has been developed, verified, and published. Results of tests on many forms of the closed conduit spillway entrance have been published. Pipe culverts laid on steep slopes may flow completely full even though the outlet discharges freely. Generalized methods for analysis and reporting of the results have been developed. The use of air as the model fluid has been verified by comparing test results with those obtained using water as the model fluid. The two-way drop inlet with the horizontal anti-vortex device causes the spillway to act as a self-regulating siphon when the headpool level approximates the anti-vortex plate elevation. The height of the anti-vortex plate above the drop inlet crest and the overhang of the anti-vortex plate determine the effectiveness of the plate as an anti-vortex device. For one form of the inlet, tests have been made to determine the crest loss coefficient, the barrel entrance loss coefficient, the pressures on the plate and the drop inlet, the general performance of the inlet, minimum and maximum permissible plate heights, and the head-discharge relationship for plate control. Variables have been the length of the drop inlet, the barrel slope, the height and overhang of the anti-vortex plate, and the sidewall thickness. Tests of low-stage orifices in the two-way drop inlet have shown that improper location and improper proportioning of the orifices can prevent priming of the spillway. The proper location and size of the orifices have been determined. To supplement the experiments, potential flow methods have been used to determine the theoretical coefficient of energy loss at the crest of the two-way drop inlet. Six shapes of elbow between the two-way drop inlet and the transition were tested. The elbows were evaluated on the basis of high minimum relative pressures and the presence of adverse pressure gradients. The theoretical free streamline elbow had small areas of adverse pressure gradient. The best elbow is an ellipse with semi-major and semi-minor axes of 2D and 1D. (D is the barrel diameter.) An elbow made up to two 45-degree circular segments of radii D/2 and 3D/2 also has generally satisfactory hydraulic characteristics. Seven transitions between the half-square crown, half-circular invert cross section at the elbow exit and the circular barrel were tested. The best transition is warped and 1D long. (See 1968 issue for details, –ed.) The entrance loss coefficients are low and identical within the limits of experimental precision for all elbow-transition combinations. Tests on the hood drop inlet have shown that the hood barrel entrancc can be used to reduce the minimum required height of the drop inlet. Minimum sizes of drop inlet and anti-vortex devices have been determined.
(*h*) **Crest Losses for Two-Way Drop Inlet**, G. G. Hebaus, *J. Hyd. Div., ASCE* **95**, HY3, pp. 919-940, May 1969.

157-00194-700-10

A STUDY OF METHODS USED IN MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS (Inter-Agency Sedimentation Project in cooperation with St. Anthony Falls Hydraulic Laboratory)

(*b*) Committee on Sedimentation, Water Resources Council; personnel of the U.S. Army Corps of Engrs. and the U.S. Geological Survey are actively engaged on the project.
(*d*) Experimental; applied research and development.

(*e*) Drawings and specifications are available to facilitate the manufacture of suspended-sediment and bed-material samplers, particle-size analyzers, and associated laboratory equipment. Approved designs for the measurement of suspended sediment include a single stage sampler, 4-, 22-, and 62-pound depth-integrating samplers, electrically operated point-integrating suspended samplers weighing 100-, 200-, and 300-pounds, and an intermittent pumping type sampler. Samplers for the measurement of bed material include a piston-type hand-operated sampler, 30-pound hand-line sampler, and 100-pound sampler for cable suspension. Additional items are a bottom-withdrawal sedimentation tube for size analysis, and visual-accumulation sedimentation tubes with recording equipment for particle size analyses of sands. The primary objective of the current program is the development of an instrument to automatically record suspended-sediment concentration in flowing streams.

(*g*) Testing has continued on the intermittent pumping-type samplers, impact hydrophones, electrical and nuclear sensing devices. Results of field tests on bottling-type pumping samplers are favorable. Laboratory tests have been completed on a pumping sampler with a 72-pint-size sample bottle capacity. A control that automatically adjusts the frequency of pumping sampler operation to match stream discharge has been revised and is currently being field tested. A Fischer-Porter water level recorder was modified to include an event marker device that would record on the paper tape the time each pumped sample was taken. Sampler can also be cycled by a signal from the Fischer-Porter recording unit. Laboratory tests on an electrical impedance device indicate that the method is a reasonably reliable means for rapidly determining the concentration of suspended-sediments in a stream. Peripheral water conditioning equipment and electrical controls for a field installation are being designed. Field tests on the radiological sedimentation gauges have produced favorable relationships, however, maintenance costs have been excessive in both time and money.

(*h*) **Instruments and Reports for Fluvial Sediment Investigations, Federal Inter-Agency Sedimentation Project,** 57 pages, Rev. Feb. 1971, $1.00 per copy. For sale by the District Engr., St. Paul District, Corps of Engrs., 1217 U.S. Post Office and Custom House, St. Paul, Minn. 55101.

157-01168-350-05

A STUDY OF CANTILEVERED OUTLETS

(*b*) Agricultural Research Service, U.S. Dept. of Agric. in cooperation with Minnesota Agric. Expt. Sta. and St. Anthony Falls Hydraulic Laboratory.

(*d*) Experimental; generalized applied research for design.

(*e*) Pipe outlet conduits for small spillways are frequently cantilevered beyond the toe of the earth dam. Attempts are being made to determine quantitatively the size of the scour hole to be expected under various field conditions. Rectangular cantilever outlets with a deflector at the exit to throw the water away from the structure and move the scour hole further downstream are also scheduled for investigation.

(*g*) The ratio of the volume-depth d′ (the cube root of the scour volume below the operating water level), the average width W of the scour hole at the operating water level and the maximum depth d of the scour hole below the operating water level to the pipe diameter D were determined for horizontal cantilevered pipes 1D and 4D above a sand bed composed of 1, 2, and 4 mm sands having a standard deviation of 1.1. Relative discharges $Q/D^{5/2}$ of 5, 7.5, 10, 15, 20, 25 and 30 were used. The operating water level was slightly below the surface of a horizontal sand bed in which a trapezoidal channel 1D deep with a 6D bottom width and 1 on 2 side slopes had been formed. The scour was usually measured at varying times up to 3 days. The resulting relationships $d'/D = \theta/196\phi$, $W/D = (\theta/156\phi)^{4/3}$, and $d/D = (\theta/270\phi)^{4/5}$, with $\theta = 52.9 (V_o/V_f)^{-1/2} + \log V_oT/D - 7.0$ and $\phi = (V_o/V_f)^{-3/2}$ where V_o is the velocity in the pipe, V_f is the shear velocity, and T is the time from the initiation of scour.

(*h*) **Model Study of Scour from Cantilevered Outlets,** A. R. Robinson, *Trans., ASAE* **14,** 3, pp. 571-576, 581, 1971.

157-05500-530-21

HYDRODYNAMIC FLUTTER OF SUPERCAVITATING HYDROFOILS

(*b*) Naval Ship Res. and Dev. Ctr., Dept. of the Navy.

(*d*) Experimental, basic research.

(*e*) Flat-plate hydrofoils are tested in a free-jet water tunnel at supercavitating conditions to determine the critical velocity as a function of the mass density ratio and other variables. The main purpose is to check the existing theories.

(*f*) Completed.

(*g*) Critical speeds for the two-degree of freedom flutter of a two-dimensional flat plate were measured. The critical flutter speed was found to be very sensitive to the location of the separation point. It was also revealed that the cavity may be pinched off when the amplitude of flutter is sufficiently large.

(*h*) **Flutter of Supercavitating Hydrofoils–Comparison of Theory and Experiment,** C. S. Song, to be published in *J. Ship Research.*

157-05795-250-21

NON-NEWTONIAN BOUNDARY LAYER

(*b*) Naval Ship Res. and Dev. Ctr. and Office of Naval Research, Dept. of the Navy.

(*d*) Experimental.

(*e*) Study of boundary layer structure as influenced by the injection of concentrated solutions of high molecular weight polymers at the boundary.

(*f*) Completed.

(*g*) Measurements of the velocity profile and polymer diffusion were made in a plane boundary layer with length varying up to 40 feet, thickness varying up to 15 inches, and Reynolds number varying up to 8×10^7. Aqueous solutions of Polyox WSR-301 of 250 to 2000 ppm were injected tangentially at the boundary near the origin of a boundary layer having a stream velocity of 18 fps. Drag reductions up to 35 percent were obtained.

(*h*) **Shear and Diffusion in a Large Boundary Layer Injected with Polymer Solution,** J. M. Wetzel, J. F. Ripken, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 114*, Feb. 1970. (Not available for distribution.)

157-06735-250-20

SURFACE PRESSURE FLUCTUATION IN DILUTE SOLUTION OF DRAG REDUCING POLYMERS

(*b*) Office of Naval Research, Dept. of the Navy.

(*d*) Experimental.

(*e*) Measurements were made of the surface pressure fluctuation under the boundary layer developed on a rotating cylinder as influenced by various concentrations and types of drag reducing polymers.

(*f*) Completed.

(*g*) Surface pressure fluctuation intensity was found to be reduced at high frequencies in proportion to friction factor reduction.

(*h*) **The Influence of Drag Reducing Polymer Additives on Surface Pressure Fluctuations on Rough Surfaces,** J. M. Killen, in preparation.

157-06744-040-54

FREE STREAMLINE FLOW OVER DISCONTINUITIES IN A BOUNDARY LAYER

(*b*) National Science Foundation.

(*d*) Theoretical and experimental; Doctoral thesis.

(*e*) To understand the mechanism of cavity formation at an obstruction in a boundary layer subjected to low pressures. Calculations have been made to describe the boundary cavity formed by various kinds of discontinuities that are often found in hydraulic structures. Experiments are being made to measure the cavity properties.

157-07661-060-20

WAVES IN STRATIFIED FLUIDS

(*b*) Office of Naval Research, Dept. of the Navy.
(*d*) Experimental.
(*e*) An experimental facility is being developed wherein progressive waves of specified characteristics in stratified fluid could be produced.

157-07662-710-21

AN EVALUATION OF THE ACOUSTIC GAS NUCLEI SIZE DISTRIBUTION INSTRUMENT

(*b*) Naval Ship Res. and Dev. Ctr., Dept. of the Navy.
(*d*) Experimental.
(*e*) Perform a complete evaluation of the acoustic attenuation method for determining the gas nuclei size distribution in water.
(*f*) Completed.
(*g*) The general conclusion was reached that acoustic methods are not sensitive enough to obtain the details required for most purposes in cavitation inception research.
(*h*) **An Evaluation of Acoustic Techniques for Measuring Gas Bubble Size Distributions in Cavitation Research,** F. Schiebe, J. M. Killen, Univ. of Minn.,. *St. Anthony Falls Hydraulic Lab. Proj. Rept. 120*, May 1971. (Not available for distribution.)

157-07673-870-52

STATE-OF-THE-ART OF MODELING HEAT SPREAD INTO LAKES

(*b*) Argonne National Laboratory, U.S. Atomic Energy Commission.
(*d*) State-of-the-art survey of physical (hydraulic) modeling of heat dispersion from condenser cooling discharges to lakes.
(*f*) Completed.
(*h*) **Physical (Hydraulic) Modeling of Heat Dispersion in Large Lakes, A Review of the State-of-the-Art,** E. Silberman, *ANL/ES-2*, Argonne Natl. Lab., Aug. 1970. (Available from NTIS, Springfield, Va. 22151.

157-07677-220-05

SCOUR AND PROTECTION AGAINST SCOUR AT STRUCTURES

(*b*) Agricultural Research Service, U.S. Dept. of Agric., in cooperation with the Minnesota Agric. Expmt. Sta. and the St. Anthony Falls Hydraulic Laboratory.
(*d*) Experimental; generalized applied research for development and design.
(*e*) Determine the need for protective riprap, the area requiring protection, and the size of riprap required at the inlet and outlet of a box inlet drop spillway proposed for Tillatoba Creek, Yazoo River Watershed, Tallahatchie County, Miss.; and laboratory studies to determine for the box inlet drop spillway, the straight drop spillway, and the SAF stilling basin, the size and shape of the scour in sand beds and the size and placement of riprap to protect against scour.
(*g*) A compound trapezoidal weir was developed for the box inlet drop spillway to choke the spillway crest and insure bank full channel flow at the spillway for bank full channel capacity flow. This will prevent the overbank flow from eroding the channel banks when it returns to the channel near the spillway. The procedure described in National Cooperative Highway Research Program Report 108 was used to design the riprap size and placement upstream of the spillway crest and eliminate the 14-foot deep by 105-foot wide by 50-foot long scour of the original sand bed. The initial design, based on measured velocity contours with the flow approaching the spillway, proved to be completely satisfactory. Downstream of the spillway a riprap blanket 9 inches thick of 3-pound median and 9-pound maximum size stone provided adequate protection where the channel shape closely approximated the self-scoured shape. In contrast, a blanket 36 inches thick of 36-pound median and 780-pound maximum size riprap was required over a larger area to protect the channel from scour when the riprap encroached on the self-scoured channel shape.
(*h*) **Model Test of Box Inlet Drop Spillway and Stilling Basin Proposed for Tillatoba Creek, Tallahatchie County, Mississippi,** F. W. Blaisdell, Soil and Water Cons. Res. Div., Agric. Res. Service, U.S. Dept. of Agric., *ARS 41-190*, publication pending.

157-08289-230-21

NEW INSTRUMENTATION FOR THE MEASUREMENT OF THE CAVITATION SUSCEPTIBILITY OF WATER

(*b*) Naval Ship Research and Development Center, Dept. of the Navy.
(*d*) Applied research, experimental and analytical.
(*e*) The cavitation performance in terms of the number of cavitation events per second of a standard, analytically derived body may be related to the nuclei size distribution entrained in the test fluid and interpreted as an indication of the cavitation susceptibility of the fluid.
(*h*) **The Measurement of the Cavitation Susceptibility of Water Using Standard Bodies,** F. R. Schiebe, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 118*. (Not available for distribution.)

157-08290-250-21

RISING BODY TEST FACILITY FOR THE INVESTIGATION OF THE EFFECTS OF DRAG REDUCING POLYMERS ON FLOW NOISE, DRAG, AND SURFACE PRESSURE FLUCTUATION

(*b*) Naval Ship Research and Development Center, Dept. of the Navy.
(*d*) Experimental applied.
(*e*) The construction of a rising body test facility is expected to be useful in the measurement of drag, surface pressure fluctuations, and radiated noise from test bodies in relative motion with a liquid. The rising body test facility was chosen as a configuration with a minimum of moving parts to cause extraneous noise and vibration which at the same time provides the possibility of a relatively simple hydrodynamic form for a test body.

157-08291-250-54

FLOW MECHANISM OF THE ZERO-CROSSING RATE FOR LOCAL SHEAR MEASUREMENTS IN FLOWING FLUID

(*b*) National Science Foundation.
(*d*) Experimental.
(*e*) Examine in detail the physical processes involved in the correlation of a zero-crossing rate of heat transfer fluctuations from hot-film probes with relevant flow properties in shear flows. The problem of shear (drag) reduction by polymer additives to water will be studied as a test case.

157-08292-690-34

HYDRAULIC DISINTEGRATION OF ROCK FOR RAPID EXCAVATION

(*b*) U.S. Bureau of Mines.
(*d*) Experimental applied research.
(*e*) An attempt to disintegrate hard rock by impacting with a water mass of about one pound at velocities up to 1000 fps, intended to be used in rapid excavation of tunnels.
(*f*) Completed.
(*g*) Instability and breakdown of air-water interface prevented effective delivery of disintegrating level of impact pressures.
(*h*) **A Study of the Fragmentation of Rock by Impingement with Water and Solid Impactors,** J. F. Ripken, J. M. Wetzel, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 131*. (Available from NTIS.)

157-08293-350-70

TACONITE DIKE STUDY

(*b*) U.S. Steel, Mt. Iron, Minn.
(*d*) Experimental and theoretical.
(*e*) The properties of taconite tailings were determined. Seepage analysis of embankments composed of coarse and fine tailings were made. Finally slope stability analyses of proposed embankment designs were analyzed by a computer program.
(*f*) Completed.
(*g*) Seepage quantity is expected to be very low and of high quality. Embankment schemes proposed are adequate with factors of safety being determined for all schemes proposed.
(*h*) **Seepage and Stability Analysis of Taconite Tailings Basin,** J. W. Hayden, P. Christiano, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 125*, July 1971. (Not available for distribution.)

157-08294-810-33

UPPER MIDWEST FLOOD FORECASTING

(*b*) Office of Water Resources Research.
(*d*) Analytical; applied research.
(*e*) Initial phase concerns the assembly of pertinent data on spring floods in the upper midwest. This data includes runoff, precipitation, air temperatures, solar radiation, and water content of the snowpack. This data will be used to analyze recorded flood events to better understand the various snowmelt and runoff functions that combine to produce record floods.

157-08295-870-36

STORM WATER DROPSHAFT

(*b*) Environmental Protection Agency.
(*d*) Theoretical and experimental, applied research; Doctoral thesis.
(*e*) Examine the nature of two-phase flow under cavitating conditions in long vertical conduits to provide design data for its application as dropshaft for low level drainage conduits.
(*f*) Completed.
(*g*) The change in state of the fluid and the hydraulic conditions were delineated. The cavitation has a significant effect on discharge.
(*h*) **Hydraulics of Long Vertical Conduits and Associated Cavitation,** A. G. Anderson, P. P. Vaidyaraman, *Water Pollution Control Series*, EPA, June 1971. (Available from the Supt. of Documents, Government Printing Office, Washington, D.C. 20242.)
The Nature of Flow in Long Vertical Conduits with Reference to the Occurrence of Cavitation and Compressible Flow Transitions, P. P. Vaidyaraman, *Ph.D. Thesis*, Univ. of Minn., 1972.

157-08296-060-36

MIXING AND DISPERSION AT A WARM WATER OUTLET

(*b*) Environmental Protection Agency, Water Quality Office.
(*d*) Experimental, theoretical and field investigation; basic research.
(*d*) The hydrodynamics of flow of heated water from channels into lakes and reservoirs was studied.
(*f*) Completed.
(*g*) A three-dimensional buoyant jet-type model has been developed to predict the main trajectory, velocity and temperature in surface plumes. Experimental laboratory and field data have been analyzed to show entrainment and spread characteristics of the heated jet. The two-dimensional mixing internal hydraulic jump has been analyzed theoretically and experimentally.
(*h*) **Surface Discharge of Heated Water,** H. Stefan. Rept. to be published, *Water Pollution Control Series*, Environmental Protection Agency.

157-08297-230-75

GURI CAVITATION STUDY

(*b*) Harza Engineering Company, Chicago.
(*d*) Experimental applied research.
(*e*) Investigation of cause and cure of cavitation erosion of lip of flip bucket spillway of Guri Hydroelectric Project in Venezuela.
(*f*) Completed.
(*g*) Damaging conditions traced to transient negative pressure pulses caused by unique tailwater conditions.
(*h*) **Hydraulic Model Studies for the Guri Hydroelectric Project, Report on Spillway Cavitation Damage,** J. F. Ripken, W. Q. Dahlin, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 132*, Feb. 1972. (Not available for distribution.)

157-08298-350-75

HYDRAULIC MODEL STUDIES OF SPILLWAY STRUCTURE, NADER SHAH PROJECT, IRAN

(*b*) Harza Engineering Company, Chicago.
(*d*) Experimental design.
(*e*) Examine the hydraulic operation of the spillway and associated components.

157-08299-870-75

ST. PAUL STORM RUNOFF DATA

(*b*) Horner and Shifrin, St. Louis, Missouri.
(*d*) Analytical, and field investigation; applied research.
(*e*) For the proper design of improvements to the City of St. Paul combined sewer system it was necessary to estimate storm runoff hydrographs. Computer monitored water levels, gate positions and inflatable dam pressures were used to calculate discharges resulting from storms during the summer of 1970.
(*f*) Completed.
(*g*) Some difficulty was encountered in determining the elevation of the inflatable dam crest. Upper and lower levels of discharge were determined from possible geometry of inflatable dam. Most probable discharge was then established based on relative water levels and pressure in dam during runoff event.

157-08300-350-75

HYDRAULIC MODEL STUDIES OF THE ACARAY RIVER DEVELOPMENT–YGUAZU DAM

(*b*) Chas. T. Main, Intl., Boston, Mass.
(*d*) Experimental, design.
(*e*) Study of spillway, stilling basin, bottom outlet, and gates in outlet including hydroelastic effects.

157-08301-210-75

LaSALLE STORM SEWER

(*b*) Chamlin and Associates, Peru, Illinois.
(*d*) Experimental, applied research and design.
(*e*) Research on principles of helical flow in pipes. Immediate objective was to obtain friction factors for design.
(*f*) Completed.
(*g*) The following empirical friction factor formula was derived from the data: $f = 0.945 \times 10^{-8}\, \Theta^{3.64}\, D^{-0.41}$, where Θ is the angle in degrees between the pipe axis and a tangent to the corrugation and D is the inside pipe diameter in feet. Data used in developing the formula were obtained for $52° \leq \Theta \leq 90°$; $0.67 \text{ ft} \leq D \leq 5.5$ ft. and the pipe seams are lapped or riveted but not bolted.
(*h*) **Further Studies of Friction Factors for Corrugated Aluminum Pipes Flowing Full,** E. Silberman, W. Q. Dahlin, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 121*, Apr. 1971. (Not available for distribution.)
Effect of Helix Angle on Flow in Corrugated Pipes, *J. Hydraul. Div., ASCE* HY11, 2253-2263, Nov. 1970. (Limited copies available.)

157-08302-340-75

ENCINA POWER PLANT

(*b*) Pioneer Service and Engineering Co., Chicago.
(*d*) Experimental project, model study.
(*e*) Model study of existing intake facilities to determine if they will satisfactorily meet the needs of the expanding plant capacity. Various alternatives were examined and final recommendations have been made.
(*f*) Completed.
(*g*) Substantial modifications of existing intake facilities have been recommended to meet growing demand for cooling water for expanded plant capacity.
(*h*) **Model Study of Proposed Expansion–Encina Power Plant San Diego Gas and Electric Company,** J. W. Hayden, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 129*, Sept. 1971. (Not available for distribution.)

157-08303-340-73

PRAIRIE ISLAND NUCLEAR PLANT

(*b*) Northern States Power Company, Minneapolis, Minn.
(*d*) Experimental, design.
(*e*) Study of warm water recirculation, cooling tower basin and mixing basin.
(*f*) Completed.
(*g*) Structures were designed to provide optimum conditions based on the model studies.

157-08304-870-60

SEWER TRANSITION TESTS

(*b*) Minnesota Highway Department.
(*d*) Experimental; design.
(*e*) A model study is being made to evaluate the energy loss of a proposed transition section in an existing combined sewer. The transition is required to carry flow under a new State highway.

157-08305-720-21

FEASIBILITY AND MODEL STUDY OF 36-INCH WATER TUNNEL

(*b*) Naval Ship Research and Development Center, Dept. of the Navy.
(*d*) Feasibility study based on old and new experimental studies.
(*e*) Establish a feasible preliminary design for a large variable pressure, free-surface, high speed hydrodynamic test facility.

157-08306-250-21

EFFECT OF DRAG REDUCING POLYMERS ON RADIATED FLOW NOISE

(*b*) Naval Ship Research and Development Center, Dept. of the Navy.
(*d*) Experimental.
(*e*) An experimental study to determine the effects of drag reducing polymers on the intensity and frequency of radiated flow noise from a rotating rough cylinder.
(*f*) Completed.
(*g*) Radiated noise was found to be reduced in proportion to surface shear reduction.
(*h*) **The Influence of Drag Reducing Polymer on Radiated Noise from Rough Surfaces,** J. M. Killen, Univ. of Minn., *St. Anthony Falls Hydraulic Lab. Proj. Rept. 123.* (in preparation).

SANDIA LABORATORIES, Department of Aerodynamic Research, Organization 5640, P.O. Box 5800, Albuquerque, N.Mex. 87111. Dr. K. J. Touryan, Department Manager.

158-08265-000-52

STABILITY OF LIQUID FILMS

(*b*) U.S. Atomic Energy Commission.
(*c*) William S. Saric.
(*d*) Experimental and theoretical.
(*e*) Experimentally and theoretically identify the regions of stable and unstable behavior of a liquid layer interacting with a supersonic airstream. This models the liquid-gas configuration that is present in ablating layers or transpiration cooling systems.
(*g*) The wave motion was recorded electronically, using two "end-effect" capacitance gauges, and photographically, using spark microphotographs and high-speed motion picture cameras. Linear and nonlinear analyses have identified the dominant instability mechanism as the supersonic pressure perturbation. The theory shows that disturbances do not grow indefinitely but achieve steady-state waves, qualitatively in agreement with the experiments. The predicted amplitudes and their corresponding wavelengths and phase speeds are compared with those observed experimentally as functions of Reynolds number, shear stress and liquid properties.
(*h*) **Nonlinear Kelvin-Helmholtz Instability,** A. H. Nayfeh, W. S. Saric, *J. Fluid Mechanics* **46,** 2, pp. 209-231, 1971.
Stability of a Liquid Film, A. H. Nayfeh, W. S. Saric, *AIAA J.* **9**, 4, pp. 750-752, 1971.
An Experimental Investigation of the Stability of a Thin Liquid Layer Adjacent to a Supersonic Stream, W. S. Saric, B. W. Marshall, *AIAA J.* **9,** 4, pp. 1546-1553.
An Experimental Investigation of a Liquid Film on a Horizontal Flat Plate in a Supersonic Stream, B. W. Marshall, *Ph.D. Thesis*, Dept. of Mech. Eng., Oklahoma State University, Stillwater, Okla., 1971.
A Capacitance Depth Gauge for Thin Liquid Films, B. W. Marshall, W. G. Tiederman, *Rev. of Sci. Instruments*, in press.
Nonlinear Waves in a Kelvin-Helmholtz Flow, A. H. Nayfeh, W. S. Saric, *J. Fluid Mechanics.*
Nonlinear Stability of a Liquid Film Interacting with a Supersonic Stream, A. H. Nayfeh, W. S. Saric, *Research Rept. SC-RR-710042*, to be published. Request from author.
Experiments on the Stability of a Liquid Film Interacting with a Supersonic Turbulent Stream, W. S. Saric, to be published. Request from author.
Stability of Axisymmetric Liquid Films, W. S. Saric, R. J. Gibbons, *Research Rept. SC-RR-710019*, to be published. Request from author.

158-08266-020-52

STATISTICAL TURBULENCE

(*b*) U.S. Atomic Energy Commission.
(*c*) R. L. Fox.
(*d*) Theoretical.
(*e*) Develop tractable statistical methods for calculating turbulent flow parameters without reliance on empirical parameters.
(*g*) The turbulence field is modeled by a fluid of non-conservative interacting pseudo-particles. The statistical relations for the pseudo-particles are developed in such a manner as to reproduce the Navier-Stokes eqations for an incompressible turbulent fluid when appropriate averages are applied. Comparison of predicted results for homogeneous isotropic media is in reasonable agreement with experimental data.
(*h*) **Development of Equations for the Distribution Functions in a Turbulent Fluid Using Velocity Moments,** R. L. Fox, to be published.
Solution for Turbulent Correlations Using Multipoint Distribution Functions, R. L. Fox, *Phys. Fluids* **14,** pp. 1806, 1971.

Solution for the Correlation Functions in a Homogeneous Isotropic Incompressible Turbulent Field, R. L. Fox, *Research Report SC-RR-70-912*. Request from author.

Solution for the Three-Dimensional Energy Spectrum in a Homogeneous Isotropic Incompressible Turbulent Field, R. L. Fox, *Research Report SC-RR-720089*. Request from author.

SCIENCE APPLICATIONS, INCORPORATED, 1701 North Fort Myer Drive, Suite 908, Arlington, Va. 22209. Dr. William Layson, Vice-President.

160-08267-220-00

FLUID DYNAMICS OF EROSION

(*c*) Dr. F. D. Hains, Scientist.
(*d*) Theoretical, applied research.
(*e*) Theoretical model for spatially periodic erosion of a sand bed by ocean waves. Phenomenon is related to ablative patterns observed on some hypersonic reentry nosetips. Research being extended to ground erosion from nuclear blasts.
(*g*) Consideration of a three-layer system consisting of a boundary layer sandwiched between an outer hyperbolic flow and an erodible surface. Results indicate viscous flows over erodible surfaces can have steady state solutions which are spatially periodic.
(*h*) **Cross-Hatched Erosion Patterns at the Beach,** F. D. Hains, *Phys. Fluids* **14**, 12, 1971.

160-08268-060-00

STABILITY OF VISCOUS STRATIFIED SHEAR FLOWS

(*c*) Dr. F. D. Hains, Scientist.
(*d*) Theoretical, applied research.
(*e*) Computer codes were developed to compute the stability of a viscous, incompressible shear flow with density stratification. The effects of viscosity on flow stability were sought.
(*g*) Two unstable modes, related to Taylor-Goldstein and Tollmein-Schlichting waves, were found. Investigation being extended to variable kinematic viscosity.
(*h*) **The Stability of a Viscous Heterogeneous Shear Flow,** F. D. Hains, *U.S. Air Force SAMSO-TR-68-411*, July 1968.

UNIVERSITY OF SOUTHERN CALIFORNIA, Department of Mechanical Engineering, University Park, Los Angeles, Calif. 90007. Professor Raymond C. Binder.

161-07640-390-00

HIGH VELOCITY AIR DISTRIBUTION SYSTEMS

(*c*) Prof. E. Kent Springer and Donald C. Glover.
(*d*) Study extended to include major design criteria. Engineer in Mechanical Engineering thesis.
(*e*) A digital computer program was developed and tested by laboratory evaluation which will size the ducts and predict velocity and head loss in a system.
(*f*) Completed.
(*g*) A valid digital computer program for duct sizing and blower requirements of a multiple take-off, high velocity air conditioning system was developed.
(*h*) Thesis.

161-08269-710-00

STUDY OF THE USE OF COLOR IN SCHLIEREN PHOTOGRAPHY

(*d*) Ph.D. thesis, basic experimental work.
(*e*) The various techniques for introducing color into a Schlieren system were explored, and all of them were found to have drawbacks such that the added dimension of color in a Schlieren has never been utilized for extensive quantitative measurements. An entirely new technique using a diffraction grating to produce the color has been introduced as a modification of the conventional Schlieren system. It provides solutions to the problems of sensitivity, range of measurement deflection and undesirable effects of diffraction which have limited the usefulness of color systems in the past. Methods for analyzing a conventional Schlieren have been modified for the analysis of a color Schlieren result. Surface pressures and flow field analysis for some simple two-dimensional airfoil shapes have been obtained by these color techniques developed here, and the results compare very well with theoretical pressure calculations.
(*f*) Completed.

161-08270-390-75

SINGLE, DUCT-ENCLOSED AIR CONDITIONING SYSTEM

(*b*) James A. Knowles and Associates.
(*c*) Professor E. Kent Springer.
(*d*) Laboratory evaluation of a joist enclosed heating and cooling system for multiple unit dewellings.
(*e*) Mock-up of typical system was used as a basis of evaluation for determining performance characteristics.
(*f*) Completed.
(*g*) Recommendations for redesign were made.
(*h*) Letter report.

UNIVERSITY OF SOUTHERN CALIFORNIA, Foundation for Cross-Connection Control Research, School of Engineering, University Park, Los Angeles, Calif. 90007. Dr. E. Kent Springer, Foundation Director.

162-00049-860-73

FOUNDATION FOR CROSS-CONNECTION CONTROL RESEARCH

(*b*) Sustaining membership of local, state and federal health and water agencies as well as provincial health and water agencies in the U.S. and Canada.
(*d*) Experimental laboratory and field investigations; basic and applied research; sponsored and theses (M.S., Engr., and Ph.D.).
(*e*) Sponsored–evaluation of various back-flow prevention devices under both laboratory and field conditions. Laboratory–a new hydraulic research laboratory has been established with capabilities of up to 4500 gpm at 300 ft. head. The new facility includes parallel circuits and flow meter calibration capabilities for all sizes up through 16 inches. Equipped for short-course instructional and certification programs.
(*g*) Standarized laboratory and field evaluation procedures as well as minimum design and operating specifications have been established for back-flow prevention due to cross-connections. Greatly expanded recognition of the cross-connection control problem by Local, State, Federal and Provincial agencies as well as manufacturers has brought this work of protecting the potable water supply into sharp focus. A major contribution of this program has been the development of the 5-day short course and the one-day seminars given both at the Foundation and at agency sites to aid water and health agencies to cope with this cross-connection control problem.
(*h*) **Manual of Cross-Connection Control,** –4th Edition.
Specifications for Back-Flow Prevention Devices, 69-2.
Cross Talk, a quarterly publication of development news pertaining to cross-connection control.
List of Approved Backflow Prevention Devices, published several times per year as changes in the "List" occur.

SOUTHEASTERN MASSACHUSETTS UNIVERSITY, Electrical Engineering Department, College of Engineering, North Dartmouth, Mass. 02747.

163-08271-250-22

DRAG REDUCTION BY USING MAGNETOHYDRODYNAMIC BOUNDARY-LAYER CONTROL

(*b*) Naval Underwater Systems Center.
(*c*) Drs. G. F. Anderson, Y. K. Wu.
(*d*) Theory; applied research.
(*e*) Investigate the feasibility of stabilizing the boundary-layer of flow over a submerged body by use of magnetic fields in order to reduce the hydrodynamic drag on a torpedo.
(*f*) Suspended.
(*g*) Two-dimensional magnetohydrodynamic boundary-layer flow with suction or injection is studied, assuming that a constant magnetic field fixed to a flat plate is applied perpendicular to the plate. Computer results corresponding to several values of magnetic parameter indicate the possibility of practical drag reduction scheme by using proper combination of noise-free magnetohydrodynamic boundary-layer control, and suction and/or injection of high permeability and high conductivity material.

SOUTHERN ILLINOIS UNIVERSITY, School of Engineering and Technology, Fluid Mechanics Laboratory, Carbondale, Ill. 62901. Dr. Philip K. Davis, Chairman, Department of Engineering Mechanics and Materials.

164-07641-690-50

STUDIES OF THE FLOW, BONDING AND DAMPING CHARACTERISTICS OF A SQUEEZE FILM UNDER DYNAMIC CONDITIONS

(*b*) National Aeronautics and Space Administration.
(*d*) Experimental and theoretical; basic research.
(*e*) The research consists of a series of experimental flow, bonding, and damping characteristics of a liquid squeeze film under dynamic conditions.
(*g*) The effect of viscosity, film thickness and load pulse duration on the bonding strength has been determined. The effect of kinematic viscosity, film thickness, and frequency on the damping properties have been studied.
(*h*) **Bonding and Flow Properties of Liquid Squeeze Films,** D. Colclasure, *Thesis*, Southern Ill. Univ. Library.
A Study of the Damping Characteristics of the Liquid Squeeze Film, T. Yabe, *Thesis*, Southern Ill. Univ. Library.
The Dynamic Liquid Squeeze Film, R. C. Riepe, *Thesis*, Southern Ill. Univ. Library.
Damping Characteristics of the Liquid Squeeze Film, presented at *5th Southeastern Conf. on Theoretical and Applied Mechanics*, Apr. 1970, to be published in the proceedings.
The Dynamic Liquid Squeeze Film, presented at *6th Southeastern Conf. on Theoretical and Applied Mechanics*, Mar. 1972, to be published in the proceedings.

164-07642-020-00

TURBULENT MIXING IN ZONES OF SEPARATION

(*b*) S.I.U. Office of Research and Projects.
(*c*) Dr. Sedat Sami, Assoc. Professor.
(*d*) Experimental; basic research (Master's theses).
(*e*) Velocity and pressure fields of the mixing zone for various boundary geometrics.
(*g*) The flow characteristics in the immediate vicinity of an orifice were found to display departures from the well-known nozzle efflux characteristics. The presence of a vena contracta, the curvature of the nominal boundaries of the mixing zone and the potential core were observed.
(*h*) **Near Field Turbulence Characteristics for Axi-Symmetric Flow From an Orifice,** K. B. Jordan, *M.S. Thesis*, Southern Ill. Univ. Library, 1970.
Characteristics of Turbulence in the Separation Zone of a Two-Dimensional Conduit Flow, R. D. Acuff, *M.S. Thesis*, Southern Ill. Univ. Library, 1971.

164-07645-630-00

CHESTOSKY PUMP STUDIES

(*b*) Southern Illinois University Foundation–S.I.U. office of Research and Projects.
(*c*) Dr. James L. Evers, Asst. Professor.
(*d*) Theoretical and experimental; applied research.
(*e*) Evaluate a variable flow, positive displacement, vane type pump, designed and patented by Mr. Robert Chestosky. In particular, the performance data that is essential in determining the applicability of this device to specific needs are being obtained. Theoretical parameters that can be obtained by considering the pump geometry are also being determined.
(*f*) Completed.
(*h*) **A Developmental Study of the Hemispheric-Section Chamber Positive Displacement Pump,** J. B. Park, *M.S. Thesis*, Southern Ill. Univ. Library, 1971.

164-08272-050-00

ROUND TURBULENT JET

(*b*) S.I.U. Office of Research and Projects.
(*c*) Dr. Sedat Sami, Assoc. Professor.
(*d*) Theoretical, experimental; basic research.
(*e*) Evaluation and analysis of the round turbulent jet data with the use of the general equations of mean flow.
(*f*) Completed.
(*g*) The potential core of the jet was defined in terms of the positive pressure field present immediately downstream from the nozzle and similarity of velocity profiles was achieved in the mixing zone using the nominal boundaries of such a "core."
(*h*) **Some Details of the Pressure and Velocity Fields Near the Nozzle of a Round Turbulent Jet,** S. Sami, *Proc., 6th Southeastern Conf. on Theoretical and Applied Mechanics*, Univ. South Florida, Mar. 1972.

SOUTHWEST RESEARCH INSTITUTE, Department of Mechanical Sciences, 8500 Culebra Road, San Antonio, Tex. 78284. H. Norman Abramson, Department Director.

165-06063-540-50

STUDIES OF LIQUID PROPELLANTS IN LOW GRAVITY

(*b*) National Aeronautics and Space Administration, Marshall Space Flight Center.
(*c*) Dr. F. T. Dodge, Sr. Research Engineer.
(*d*) Theoretical and experimental; applied research.
(*e*) Studies of forces on rocket fuel tanks caused by liquid sloshing in simulated low gravity environments.
(*g*) Sloshing characteristics for many types of tanks have been studied analytically and experimentally. A novel method of simulating low-gravity by using a magnetic fluid placed in a large solenoidal electromagnet has been developed.
(*h*) **Simulated Low-Gravity Sloshing in Cylindrical, Spherical, and Ellipsoidal Tanks,** F. T. Dodge, L. R. Garza, *AIAA J. Spacecraft and Rockets* **7**, 2, pp. 204-206, Feb. 1970.
Low-Gravity Fuel Sloshing in an Arbitrary Axisymmetric Rigid Tank, W. H. Chu, *J. Appl. Mech.* **37**, Series E, pp. 828-837, Sept. 1970.

165-06065-210-50

FLOW-INDUCED VIBRATIONS AND LOSSES IN HIGH VELOCITY DUCT SYSTEMS

(*b*) National Aeronautics and Space Administration, Marshall Space Flight Center.
(*c*) Dr. C. Richard Gerlach, Manager, Hydro-Mechanics Systems.
(*d*) Theoretical and experimental; applied research.

(e) Studies of vibration induced in metal bellows and the flow losses in such bellows and in pipe bends.
(g) An analytical model of bellows flow-induced vibration has been derived and verified. New low-loss elbow has been developed.
(h) Several SwRI technical reports and one published paper.

165-06066-510-21

HYDRODYNAMICS OF RIGID-BODY WATER IMPACT

(b) U.S. Naval Ship Research and Development Center.
(c) Dr. C. Richard Gerlach, Manager, Hydro-Mechanics Systems.
(d) Theoretical and experimental; applied research.
(e) Studies of real fluid effects in rigid-body water impact, with emphasis on the trapped air cushion; later considerations will emphasize scale effects.
(g) Have measured effect of liquid properties variations and wave motions on impact pressures.
(h) Several SwRI technical reports.

165-07648-540-50

STUDY AND ANALYSIS OF LOW-G FUEL SLOSHING

(b) National Aeronautics and Space Administration, Marshall Space Flight Center.
(c) Dr. F. T. Dodge, Sr. Research Engineer.
(d) Experimental and theoretical; applied research.
(e) Develop analysis of low-G sloshing in spheroidal and two-dimensional tanks and verify theory by experiments.
(g) Two-dimensional sloshing analysis and tests completed; computer program for spheroidal tanks underway. Theory compares very well with tests.
(h) SwRI technical reports; several papers in preparation.

165-07651-230-22

SYSTEMS ANALYSIS AND PRELIMINARY DESIGN OF CAVITATION DAMAGE TEST FACILITY FOR SURFACE-EFFECT SHIP MATERIALS

(b) Joint Surface Effect Ships Program Office, Washington, D.C.
(c) Dr. H. N. Abramson, Director, and Mr. W. E. Woolam, Sr. Research Engineer.
(d) Experimental, theoretical, and field investigation; development.
(e) Identify areas of cavitation damage on surface effect ships and formulate a preliminary design of a facility to study cavitation effects.

165-08273-210-50

MINIMUM PRESSURE LOSS IN HIGH VELOCITY DUCT SYSTEMS

(b) National Aeronautics and Space Administration, Marshall Space Flight Center.
(c) Dr. C. Richard Gerlach, Manager, Hydro-Mechanics Systems.
(d) Theoretical and experimental; applied research.
(e) A detailed scope of work is involved relating to a study of pressure loss minimization and a general improvement of flow conditions of liquids and gases in space vehicle feed systems.

165-08274-540-50

ANALYSIS OF PROPELLANT FEEDLINE DYNAMICS

(b) National Aeronautics and Space Administration, Marshall Space Flight Center.
(c) J. L. Holster, Res. Engineer.
(d) Theoretical and experimental; applied research.
(e) Provide an accurate and easily used dynamic model, and an associated computer program, which represents a typical propellant feedline.

165-08275-610-70

FUEL VALVE STUDY

(b) Honeywell Corporation.
(c) Dr. C. Richard Gerlach, Manager, Hydro-Mechanics Systems.
(d) Theoretical and experimental; applied research.
(e) Define a range of possible valve concepts employing various combinations of inputs (hydraulic, pneumatic or electrical), input interface devices, actual metering valves, and feedback means (hydraulic, mechanical, fluidic, or electrical) to produce proportional and proportional-plus-integral control functions. These concepts will then be screened to finally give several which will be subjected to more detailed analysis and evaluation.

165-08276-700-50

AN ION-TRACER ANEMOMETER FOR LOW VELOCITY GAS FLOW MEASUREMENT

(b) National Aeronautics and Space Administration, Marshall Space Flight Center.
(c) Dr. Robert L. Bass, III, Sr. Research Engineer.
(d) Theoretical and experimental; applied research.
(e) Design, construct, test, calibrate and deliver an ion-tracer anemometer (ITA) for monitoring low velocity gas flows in a spacecraft.

STANFORD UNIVERSITY, Department of Civil Engineering, Hydraulic Laboratory, Stanford, Calif. 94305. Professor E. Y. Hsu, Director of Laboratory.

166-01946-810-54

HYDROLOGIC SYNTHESIS

(b) National Science Foundation.
(c) Professor Ray K. Linsley.
(d) Theoretical and field research.
(e) A detailed digital computer model (Stanford Watershed Model) is used to investigate various interactions in the hydrologic cycle.
(h) **Hydrologic Effects of Rainfall Augmentation,** A. M. Lumb, *Dept. of Civil Engrg. Tech. Rept. 116*, Nov. 1969.

166-04219-530-21

SUPERCAVITATING HYDROFOIL THEORY

(b) Naval Ship Research and Development Center.
(c) Professor R. L. Street.
(d) Theoretical; basic research; Ph.D. theses and Postdoctoral research.
(e) Analyses are being made to develop a method for computing the flow about a supercavitating three-dimensional lifting hydrofoil having arbitrary aspect ratio and arbitrary angle of attack.
(g) Nonlinear solutions for two-dimensional and axisymmetric cavitating flows have been obtained.
(h) **Techniques for Solving Free-Streamline, Cavity, Jet and Seepage Problems by Finite Differences,** R. W. Jeppson, *Dept. of Civil Engrg. Tech. Rept. 68*, Sept. 1966.
Cambered Bodies in Cavitating Flow–A Nonlinear Analysis and Design Procedure, R. L. Street, B. E. Larock, *Dept. Civil Engrg. Tech. Rept. 72*, Dec. 1966.

166-04917-420-20

MECHANISMS INVOLVED IN WIND-GENERATED WAVES

(b) Office of Naval Research.
(c) Professors E. Y. Hsu, R. L. Street.
(d) Experimental and theoretical; basic research for Doctoral theses.
(e) Examination, experimental verification, and extension of available theories are being carried out. Several laboratory models of wind-wave phenomena are under study.
(g) The importance of the shear flow instability mechanism in the transfer of momentum from wind to wave has been established.
(h) Complete list of reports and papers available on request to correspondents.

166-05454-420-54

STUDIES ON WIND-WAVE INTERACTIONS

(*b*) National Science Foundation.
(*d*) Experimental; Ph.D. theses.
(*e*) The experiments include pressure, velocity, wave form, and spectral measurements in the region of, and at, the interface. They are designed to study the mechanism of energy transfer between the air and the water.
(*g*) At the present time there appears to be a well-argued wave generation theory, yet the data in hand give only qualitative verification of the theory. Order of magnitude disagreement arises between theory and experiment in the case of wave growth rates.
(*h*) Complete list of reports and papers available on request to correspondents.

166-06225-420-54

STUDIES OF MASS AND ENERGY TRANSPORT ACROSS AN AIR-WATER INTERFACE

(*b*) National Science Foundation.
(*c*) Professor R. L. Street.
(*d*) Experimental, laboratory invstigation; basic research for Ph.D. dissertations.
(*e*) Detailed experimental measurements are to be made to obtain quantitative data on latent and sensible heat transfer and mass transfer due to evaporation and spray formation at an air-water interface.
(*h*) Complete list of reports and papers available on request to correpondents.

STEVENS INSTITUTE OF TECHNOLOGY, Davidson Laboratory, Castle Point, Hoboken, N.J. 07030. Dr. John P. Breslin, Director.

167-04229-420-20

FUNDAMENTAL STUDY OF INTERACTION BETWEEN DEEP WATER GRAVITY WAVES AND LOCAL TURBULENT FLOW FIELD

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Professor Daniel Savitsky.
(*d*) Experimental and theoretical; basic research.
(*e*) Fundamental study of interaction between deep water gravity waves and local turbulent flow field.
(*f*) Completed.
(*g*) The transverse gradient of the longitudinal flow in the turbulent flow field resulted in wave height attenuations of nearly 90 percent in the flow field and wave height amplifications of nearly 75 percent in the area outside the flow field. A simple analytical solution using wave refraction, diffraction and superposition concepts is developed which qualitatively reproduces the measured results.
(*h*) Davidson Lab., *Stevens Inst. of Tech. R-1469*, Jan. 1971.

167-05935-550-21

UNSTEADY LOADS ON DUCTED PROPELLERS AND NOZZLES

(*b*) Naval Ship Research and Development Center.
(*c*) Dr. S. Tsakonas, Head, Fluid Dynamics Div., Miss W. R. Jacobs, Sr. Research Engr., M. R. Ali, Res. Engineer.
(*d*) Theoretical; applied research.
(*e*) Develop a method of determining the unsteady and steady loading on a ducted propeller and its enshrouding nozzle operating in a three-dimensional non-uniform flow field.
(*f*) Completed.
(*g*) Theory demonstrates the filtering effect of the propeller on the flow field so that the direct loading is zero at all frequencies not equal to multiples of blade frequency (i.e., blade frequency times 0, 1, 2...). A computer program adaptable to the CDC-6600 high-speed computer has been developed which evaluates the steady state and vibratory propeller-generated and duct forces and moments on the basis of the unsteady lifting surface theory.
(*h*) *Davidson Lab. Rept. 1309*.

167-07679-420-54

FLOW OVER WAVY SURFACES

(*b*) National Science Foundation.
(*c*) Dr. Richard I. Hires, Asst. Prof. of Ocean Engineering.
(*d*) Experimental; basic research.
(*e*) Measure variation in flow parameters over a rigid sinusoidal boundary. Hot-wire measurements of turbulent velocity fluctuations and pressure distribution measurements on the boundary will be taken. Results will be applied to problems of wind-wave generation.

167-07680-420-54

WIND-WAVE GENERATION WITH OPPOSING CURRENTS

(*b*) National Science Foundation.
(*c*) Dr. Richard I. Hires, Asst. Prof. of Ocean Engineering.
(*d*) Field investigation; basic research.
(*e*) Study parameters of wind-generated waves with and without an opposing tidal current. Simultaneous observations of wind, waves and current are required to determine current's influence on wave steepness. Work will be done in the Hudson River with wave and current measurements from a bottom-mounted tower.

167-07681-420-54

EXPERIMENTAL INVESTIGATION OF WAVE-CURRENT INTERACTIONS

(*b*) National Science Foundation.
(*c*) Dr. Richard I. Hires, Asst. Prof. of Ocean Engineering.
(*d*) Experimental; basic research.
(*e*) Investigate the interaction of a single-component wave train with a steady but horizontally nonuniform current, with the aim of clearly exposing the importance of the wave radiation stress in wave-current interactions. The work is being conducted in a water channel on which waves are generated pneumatically. Wave heights, lengths and periods will be measured with two resistance-type wave gages. Water speed will be determined by using hot-film anemometers.

167-07682-430-44

MOTIONS OF OCEAN PLATFORMS

(*b*) National Oceanic and Atmospheric Administration, Sea Grant Program.
(*c*) Dr. S. Tsakonas, Head, Fluid Dynamics Div., Manager, Sea Grant Program.
(*d*) Experimental and theoretical; basic and applied research.
(*e*) Develop a reliable analytic technique for predicting wave-induced motions of ocean platforms. Computer programs have been developed for predicting motions of barge-type hulls representing floating ocean platforms. The results have been found to be in good agreement with motions measured in model tests in irregular waves. In addition, a series of secondary studies are being carried out to provide basic understanding of wind-generated waves with and without currents, hydrodynamic forces on oscillating cylinders for large amplitude motions, and extreme environmental conditions.
(*h*) **Prediction of Motions of Ocean Platforms in Oblique Seas,** C. H. Kim, F. Chou, *Rept. SIT-OE-70-1*, June 1970.
Prediction of Drifting Force and Moment on an Ocean Platform Floating in Oblique Waves, C. H. Kim, F. Chou, *Rept. SIT-OE-70-2*, Dec. 1970.
Motions of Jackup Drill Rigs in Head Seas, C. H. Kim, F. Chou, *Rept. SIT-OE-71-3*, Mar. 1971.
Hydrodynamic Characteristics of Prismatic Barges, C. H. Kim, C. J. Henry, F. Chou, *Rept. SIT-OE-71-7*, Sept. 1971.
Motions of a Semi-Submersible Drilling Platform in Head Seas, C. H. Kim, F. Chou, *Rept. SIT-OE-71-8*, Dec. 1971.

167-07687-520-45

PERFORMANCE OF BARGE TRAINS IN A COASTAL SEAWAY

(*b*) Maritime Administration.
(*c*) Dr. H. Eda, Sr. Research Engineer.
(*d*) Experimental and analytical.
(*e*) Improve the performance of a tug-barge system in a coastal seaway in order to obtain greater productivity and higher operational efficiency.
(*g*) Yaw and sway motions and tow connection forces of barge trains in oblique seas were examined in model tests and in computerized procedures. Directional stability of barge trains in calm water was examined in computerized analysis utilizing captive model tests.
(*f*) Completed.
(*h*) **Barge Trains in a Coastal Seaway–Part I. Model Tests in Oblique Waves,** H. Eda, A. Ljone, *DL-R-1494*, 1970.
Barge Trains in a Coastal Seaway–Part II. Prediction of Lateral Motions and Bending Moments, H. Eda, *DL-R-1523*, 1970.
Barge Trains in a Coastal Seaway–Part III. Directional Stability and Control, H. Eda, *DL-R-1537*, 1970.

167-07696-040-20

PLANING SURFACES WITH WARP AND FLAPS

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Mr. P. Ward Brown, Mgr., Marine Craft Development Group.
(*d*) Experimental and theoretical; applied research.
(*e*) The forces, moments, and wetted areas of planing surfaces that have warped bottoms and are equipped with transom flaps have been determined; and existing planing formulae are being modified to account for the effects of warped deadrise and of flaps.
(*h*) **An Experimental and Theoretical Study of Planing Surfaces with Trim Flaps, P.** W. Brown, *DL Rept. 1463*, Apr. 1971, DDC No. AD-722,393.

167-07697-520-20

LOW-SPEED PLANING

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Dr. D. Savitsky and J. Mercier.
(*d*) Experimental; applied research.
(*e*) A study is being made of the performance of power boats in the hump region both in smooth water and waves. The intention is to develop an understanding of the mechanics of the low-speed resistance hump with a view to improving the performance of heavily loaded hulls, and to provide methods for performance prediction.

167-07698-520-21

ROUGH WATER PERFORMANCE OF PLANING BOATS

(*b*) Naval Ship Res. and Dev. Center, Dept. of the Navy.
(*c*) Mr. G. Fridsma, Res. Engineer.
(*d*) Experimental and theoretical; applied research.
(*e*) A systematic study of the performance of planing boats in irregular waves. The effect of changes in hull geometry, including length-beam ratio, deadrise, and bow form as well as load, is being studied from low speed through hump to planing speed. Loads and motions are being measured and analyzed statistically.
(*f*) Completed.
(*g*) A design procedure is presented which predicts the rough water performance of a planing hull.
(*h*) **A Systematic Study of the Rough-Water Performance of Planing Boats: Irregular Waves—Part 2,** G. Fridsma, *DL Rept. 1495*, Mar. 1971, DDC No. AD 728,788.

167-08277-520-10

SHIP MOTIONS IN CANALS

(*b*) U.S. Corps of Engineers and Panama Canal Company.
(*c*) Dr. H. Eda and Professor D. Savitsky.
(*d*) Analytical and experimental.
(*e*) Develop a mathematical model on a digital computer, to represent the dynamic behavior of ships in canals and, on the basis of results of digital simulations, to establish a guide to relationships between ship size and acceptable canal dimensions from the ship control viewpoint. Determine the feasibility of developing a computer-based simulator and of using large free-running models in a Panama Canal pilot-training facility.
(*f*) Completed.
(*g*) **Directional Stability and Control of Ships in Restricted Channels,** presented at the 1971 SNAME Ann. Mtg., *Trans. SNAME* **79,** 1971.

167-08278-550-21

THEORY AND MEASUREMENTS OF THE PROPELLER-INDUCED VIBRATORY FIELD

(*b*) Naval Ship Research and Development Center.
(*c*) W. R. Jacobs, Sr. Res. Engr., J. Mercier, Res. Engr., and S. Tsakonas, Head, Fluid Dynamics Division.
(*d*) Experimental and theoretical; applied research.
(*e*) Develop an experimental procedure and a signal-processing technique for measuring small pressure levels, and to develop a theory based on lifting surface theory for the evaluation of the pressure field generated by an operating propeller in a nonuniform inflow field.
(*f*) Completed.
(*g*) Theoretical results are in good agreement with those of experiments. The difficulty of accurately establishing by measurements the decay of small pressures beyond one propeller radius precludes determining the blade-frequency force exerted on a flat boundary by integrating the measured signatures. In contrast, integration of double the theoretical free-space pressure over the flat boundary is a feasible approach.
(*h*) *Davidson Lab. Rept. 1485.*

167-08279-550-21

AN EXACT LINEAR LIFTING-SURFACE THEORY FOR A MARINE PROPELLER IN A NON-UNIFORM FLOW FIELD

(*b*) Naval Ship Research and Development Center.
(*c*) Dr. S. Tsakonas, Head, Fluid Dynamics Division, W. R. Jacobs, Sr. Res. Engr., and M. R. Ali, Res. Engineer.
(*d*) Theoretical; applied research.
(*e*) Revise the previous mathematical model used in adapting linear unsteady lifting-surface theory to marine propellers by removing the so-called "staircase" approximation of the blade wake and replacing it by an "exact" helicoidal blade wake.
(*f*) Completed.
(*g*) Systematic calculations of steady-state and unsteady bearing forces and moments for a series of propellers show better agreement on the whole with experimental measurements than did the earlier calculations for the same series. In addition, the chordwise loading distributions are much smoother than obtained previously. However, the quantitative improvement must be weighed against a considerable increase in computer time.
(*h*) *Davidson Lab. Rept. 1509.*

167-08280-550-20

PROPELLER-INDUCED VELOCITY FIELD BY MEANS OF UNSTEADY LIFTING-SURFACE THEORY

(*b*) Office of Naval Research.
(*c*) W. R. Jacobs, Sr. Res. Engr. and Dr. S. Tsakonas, Head, Fluid Dynamics Division.
(*d*) Theoretical; applied research.
(*e*) Evaluate the vibratory velocity field induced by an operating propeller in both uniform and non-uniform inflow fields by means of lifting-surface theory.
(*f*) Completed.
(*g*) A numerical procedure adaptable to a high-speed digital computer has been developed and the existing program, which evaluates steady and unsteady propeller loadings,

the resulting hydrodynamic forces and moments, and the pressure field, has been expanded to include evaluation of the velocity field as well.
(*h*) *Davidson Lab. Rept. 1588.*

167-08281-550-21

PROPELLER-RUDDER INTERACTION WITH THICKNESS EFFECTS

(*b*) Naval Ship Research and Development Center.
(*c*) Dr. S. Tsakonas, Head, Fluid Dynamics Div., W. R. Jacobs, Sr. Res. Engr. and M. R. Ali, Res. Engineer.
(*d*) Theoretical; applied research.
(*e*) Include thickness effects of both lifting surfaces in evaluating theoretically the side force on a rudder of finite aspect ratio in the presence of a propeller operating in three-dimensional non-uniform flow and to compare the results with available experimental measurements for varous axial clearances between propeller and rudder.
(*g*) The existing program has been extended to include the effects of thickness of propeller and rudder which were previously ignored. In addition, the numerical procedure dealing with the high-order singularity in the interacting terms of the surface integral equation has been revised for greater accuracy.
(*h*) *Davidson Lab. Rept. 1589* (in preparation).

167-08282-510-22

IMPACT LOADS ON WARPED PLANING SURFACES LANDING ON SMOOTH AND ROUGH WATER

(*b*) Naval Air Systems Command.
(*c*) Mr. John Mercier, Research Engineer.
(*d*) Theoretical and experimental; applied research.
(*e*) The impact of planing surfaces on waves is analyzed according to an extension of the theory for smooth-water impacts in a way that takes account of the influence of wave kinematics.
(*f*) Completed.
(*h*) *Davidson Lab. Rept. SIR-DL-71-1514*, Mar. 1971.

167-08283-520-22

SHIP-INDUCED BOTTOM PRESSURE ON A CANAL WITH OR WITHOUT FLOATING ICE

(*b*) Arctic Research Project of the U.S. Naval Ordnance Laboratory.
(*c*) Dr. S. Tsakonas, Head, Fluid Dynamics Div. and Mr. John Mercier, Res. Engineer.
(*d*) Experimental; applied research.
(*e*) Study the effect of ice floes on pressure induced at the bottom of a canal by a moving ship model.
(*f*) Completed.
(*g*) The speed parameter has been found to be the single predominant factor influencing the pressure signature.
(*h*) *Davidson Lab. Rept. SIT-DL-70-1461*, Apr. 1970.

167-08284-520-22

STUDY OF ADDED SHIP RESISTANCE; APPLICATION OF BI-SPECTRAL ANALYSIS TECHNIQUES

(*b*) Naval Ship Systems Command General Hydromechanics Research Program.
(*c*) J. F. Dalzell.
(*d*) Experimental and analytical; applied research.
(*e*) Objectives are to apply simplified bi-spectral analysis techniques to the added resistance problem in hopes of achieving a fuller understanding of the limitations of present prediction techniques, and exploring the feasibility of cross-bi-spectral analysis as a data reduction technique.

167-08285-520-22

STUDY OF THE DISTRIBUTION OF MAXIMA OF NONLINEAR SHIP ROLLING IN A SEAWAY

(*b*) Naval Ship Systems Command General Hydromechanics Research Program.
(*c*) J. F. Dalzell.
(*d*) Analytical; applied.
(*e*) See (g).
(*f*) Completed.
(*g*) This report describes the methods and results of a digital computer simulation of a nonlinear random process analogous to one of the simpler analytical models for ship roll. The main objective of the simulation was to obtain "empirical" data on the distribution of roll maxima, and to test these data against the corresponding theoretical distribution for a random Gaussian (linear) process. Effort was made to confine the variation of parameters within ranges appropriate to ship rolling. Within this range of parameters, the frequency band of roll response is sufficiently narrow that the theoretical distribution of maxima of the corresponding linear process tends toward the Rayleigh. The results obtained by objective statistical test procedures indicate that the distribution of maxima of the nonlinear process is not Rayleigh in a substantial portion of the parameter range of interest. However, it was possible to conclude from the results that the Rayleigh assumption is reasonable for an important class of engineering predictions; that of the prediction of average, "significant" and "1/10 highest" maxima from a knowledge of the spectrum of roll.
(*h*) **A Study of the Distribution of Maxima of Nonlinear Ship Rolling in a Seaway,** *DL Report 1562*, Sept. 1971.

167-08286-530-21

PERFORMANCE ANALYSIS OF HYDROFOIL CRAFT

(*b*) Naval Ship Research and Development Center.
(*c*) Dr. Charles J. Henry, Sr. Scientist.
(*d*) Experimental; applied research.
(*e*) The computer model for hydrofoil craft simulation developed at NSRDC will be reviewed, extended, then utilized to study the response to catastrophic control failures with particular emphasis on the effects of hydrofoil geometry. Hull impact forces will be introduced in the existing program.
(*g*) After careful review, several modifications to the NSRDC simulator are being developed. A rough representation of the hull impact forces has been found in the literature.

167-08287-520-20

CATAMARAN MANEUVERING MOTION

(*b*) Office of Naval Research.
(*c*) Dr. H. Eda.
(*d*) Experimental and analytical.
(*e*) Obtain hydrodynamic force and moment derivatives of catamaran ships as function of hull spacing, rudder size, etc., in rotating-arm tests and to evaluate directional stability and maneuvering performance of these configurations through computer-based analysis utilizing hydrodynamic data obtained in the tests.

167-08288-520-20

SHIP COURSE STABILITY

(*b*) Office of Naval Research.
(*c*) Dr. H. Eda.
(*d*) Analytical.
(*e*) Examine directional stability and maneuvering performance of ships with inclusion of autopilot (or helmsman) by means of digital simulators and eigenvalue analysis and to establish the degree of dynamic course stability for satisfactory ship performance under various sea conditions.

SYRACUSE UNIVERSITY, Department of Civil Engineering, Fluid Dynamics Laboratory, Syracuse, N.Y. 13210. Dr. Wen-Hsiung Li.

168-08307-860-00

STREAM WATER QUALITY STUDY

(*d*) Theoretical study.

(*f*) Completed.
(*h*) **Effects of Dispersion on DO-Sag in Uniform Flow,** W. H. Li, *Proc. ASCE* **98**, SA1, Feb. 1972.

168-08308-870-54

DISPERSION OF POLLUTANTS IN TIDAL ENVIRONMENT

(*b*) National Science Foundation.
(*d*) Theoretical study.

UNIVERSITY OF TENNESSEE, Department of Civil Engineering, Knoxville, Tenn. 37916. Professor C. R. Walker, Department Head.

170-08309-200-61

EXPERIMENTAL FLUME INVESTIGATION OF HYDRAULIC TRANSIENTS IN RESERVOIR AND STEADY FLOW RIVER SYSTEMS

(*b*) Water Resources Research Center (Office of Water Resources Research Matching Grant).
(*c*) Dr. B. A. Tschantz, Assoc. Professor of Civil Engineering.
(*d*) Experimental research in open channel hydraulics as related to unsteady flow characteristics predictions. Research work is conducted with the M.S. programs in Civil and Engineering Mechanics Departments.
(*e*) Theoretical and experimental studies based on comparison of computer model prediction with physical laboratory time-variant depth and velocity data resulting from one-dimensional wave motion in a one-foot wide x 62 ft. long flume. The dam-break problem is included in the study.
(*f*) Three-year project is completed.
(*g*) Experimental results showed that in general, laboratory models of unsteady flows created by long translatory waves can be simulated by the TVA one-dimensional mathematical computer model "SOCH." In the dam-break study, experimental results indicated that channel roughness and slope have a significant effect on wave front velocity and height.
(*h*) **Experimental Flume Investigation of Hydraulic Transients in Reservoir and Steady Flow River Systems,** Y-C. Tseng, *M.S. Thesis*.
Effects of Downstream Conditions on the Propagation of Sudden Releases in Open Channels, M.-C. Shiao, *M.S. Thesis*.
Experimental Flume Investigation of Hydraulic Transients in River-Reservoir Systems, M. S. Bhargave, *M.S. Thesis*.
Laboratory Investigation of One-Dimensional Wave Motion in Open Channels, W. A. Miller, B. A. Tschantz, *1972 ASCE Water Resources Conference*, Atlanta, Ga.

170-08310-350-00

DAM SAFETY STUDY

(*b*) Engineering Experiment Station and Civil Engrg. Department.
(*c*) Dr. B. A. Tschantz, Assoc. Professor of Civil Engineering.
(*e*) The field and general study seeks to provide essential information for an objective appraisal of the need for direct state supervision of certain non-Federally owned dams in Tennessee with respect to safeguarding the public interest. Field investigation of number, distribution, and condition of non-Federally owned Tennessee dams, the present State and Federal control over non-Federally owned dams in Tennessee were reviewed; and the features of the statutes of states which specify direct State control over certain dams were studied and summarized. Research is conducted with the M.S. program in the Civil Engineering Department.
(*f*) One-year project is completed.
(*g*) The study showed that many important design, construction, maintenance, and operation features that could affect Tennessee non-Federal dam safety have not been incorporated; there are several dams in Tennessee which are potentially hazardous, and no existing State or Federal control provides adequate Tennessee dam safety control.
(*h*) **Safety Control of Small Dams in Tennessee,** K. N. Spencer, B. A. Tschantz, Dec. 1971.

UNIVERSITY OF TENNESSEE, Department of Mechanical and Aerospace Engineering, Knoxville, Tenn. 37916. Dr. J. F. Bailey, Department Head.

171-07704-620-20

BASIC RESEARCH IN DYNAMIC SEALING

(*b*) Office of Naval Research.
(*c*) Dr. Charles F. Fisher, Jr., Assoc. Professor.
(*d*) Experimental and theoretical; basic research conducted in conjunction with the M.S. and Ph.D. programs of the various cooperating departments.
(*e*) Basic research in fluid mechanics applicable to thin films in bearings and seals in laminar and turbulent flow. Specific applications include studies of thin film fluid flow in mechanical face seals, buffered bushing seals, porous wall channels, viscoseals and labyrinth seals. Non-Newtonian effects are incorporated.
(*h*) **A Study of Convective Inertia Effects and Methods of Controlling Gas Ingestion in Large Diameter Viscoseals,** L. H. Luttrull, Univ. Tennessee, *M.S. Thesis*, 48 pages, Mar. 1970. Published as *Rept. No. ME 70-T57-10;* DDC AD-709,160.
Application of Electron Microscopy to the Study of Surface Topography and Subsurface Microstructure in Wear, G. T. Newman, O. D. Smith, D. Matthes, C. R. Brooks, *Proc. 5th Intl. Conf. on Fluid Sealing*, H2.29-H2.40, 1971.
Laminar Flow in an Annulus with Porous Outer Wall, M. S. Tsai, H. L. Weissberg, *5th Southeastern Conf. Theoret. Appl. Mech.*, Raleigh, N.C., Apr. 1970.
Experimental Study of Fully Developed Laminar Flow in a Porous Pipe with Wall Injection, R. D. Bundy, H. L. Weissberg, *Phys. Fluids* **13**, p. 2613, Oct. 1970.
Turbulence and Inertia Effects in the Aligned Face Seal, L. R. Wilhelm, Univ. Tennessee, *Ph.D. Dissertation*, 137 pages, Aug. 1971. Published as *Rept. No. ME 71-T57-12;* DDC AD-730,723.
Basic Research in Dynamic Sealing–Annual Summary Report, C. F. Fisher, Jr., W. K. Stair, C. R. Brooks, A. J. Edmondson, T. V. Blalock, W. T. Snyder, H. L. Weissberg, Univ. Tennessee, 58 pages, Oct. 1971. Published as *Rept. No. ME 71-T57-13;* DDC AD-732,021.
Radial Flow Between a Porous and a Solid Disk, C. S. Chiou, H. L. Weissberg, *Proc. ASCE* **97**, EM6, 1759-1762, 1971.

TEXAS A & M UNIVERSITY, Department of Civil Engineering, College Station, Tex. 77843. Dr. John B. Herbich, Professor and Head, Hydraulic Engineering, Fluid Mechanics and Coastal and Ocean Engineering Division.

172-07708-410-44

SCOUR OF GULF COAST SAND BEACHES DUE TO WAVE ACTION IN FRONT OF SEA WALLS AND DUNE BARRIERS

(*b*) National Oceanic and Atmospheric Administration, Sea Grant Project.
(*c*) Professor R. E. Schiller, Jr.
(*d*) Experimental, applied research; Master's thesis and Ph.D. dissertation.
(*e*) A series of transient beach scour tests are being carried out on a laboratory wave tank using beach slopes of 1:40, 1:50 and 1:70 to arrive at beach scour profiles under various wave conditions. A computer program is being used in an attempt to measure shallow water wave reflection coefficients.
(*f*) Active to about January 1, 1973.

(*h*) *C.O.E. Report No. 139*, *TAMU-SG-71-207*, May 1971, available from Texas A & M University.

172-08311-870-48

AN INVESTIGATION OF THE EFFECTS OF CURRENTS AND WAVES ON A FLOATING OIL SLICK RETAINED BY A BARRIER

(*b*) United States Coast Guard.
(*c*) Dr. L. A. Hale, Dept. of Mech. Engrg., Dr. R. M. Sorensen, Dept. of Civil Engineering.
(*d*) Experimental, basic and applied research.
(*e*) Investigate the individual and combined effects of surface gravity waves and currents on the behavior of an oil slick retained by a floating barrier.

172-08312-400-44

INVESTIGATION OF THE HYDRAULIC CHARACTERISTICS AND DYNAMIC STABILITY OF TIDAL INLETS

(*b*) NOAA Sea Grant Program.
(*c*) Dr. R. M. Sorensen, Assoc. Professor.
(*d*) Field study of two inlets on the Texas Gulf Coast. Basic and applied results were obtained.
(*e*) Field studies of Brown Cedar Cut (natural) and Rollover Fish Pass (artificial) are being conducted. Particularly inlet hydrographic surveys, bottom sediment sampling and current measurements were conducted. Tide levels were recorded near the inlets and in the bays. Data are analyzed to investigate inlet character and stability.
(*g*) See published reports and papers.
(*h*) **Properties and Stability of a Texas Barrier Beach Inlet,** C. Mason, R. M. Sorensen, *C.O.E. Rept. 146*, Texas A & M Univ., Aug. 1971.
Characteristics and Behavior of Natural and Artificial Tidal Inlets on the Texas Gulf Coast, R. M. Sorensen, C. Mason, *Proc. WODCON IV*, New Orleans, Dec. 1971.

TEXAS A & M UNIVERSITY, College of Geosciences, Department of Oceanography, College Station, Tex. 77843. Professor Richard A. Geyer, Department Head.

173-04866-420-11

MODIFICATION OF TWO-DIMENSIONAL LONG WAVES OVER VARIABLE BOTTOM TOPOGRAPHY

(*b*) Coastal Engineering Research Center.
(*c*) Professor R. O. Reid.
(*d*) Theoretical applied research.
(*e*) Investigate the modification of free gravity waves in variable depth, including reflection and transmission, etc., with particular attention being given to the interaction of tsunamis with islands. The analysis employs numerical methods.
(*f*) Completed.
(*g*) A numerical program for evaluation of the water level response at an island to a general plane wave input is employed to estimate the spectral transfer function at various points on the island.
(*h*) **Orthogonal Coordinates for the Analysis of Long Gravity Waves Near Islands,** R. O. Reid, A. C. Vastano, *Proc. Specialty Conf. on Coastal Engineering*, *ASCE*, Santa Barbara, Calif. 1966.
Tsunami Response for Islands: Verification of a Numerical Procedure, A. C. Vastano, R. O. Reid, *J. Marine Res.* **25,** 2, 129-139, May 1967.
An Inverse Tsunami Problem, In: Tsunami in the Pacific Ocean, C. E. Knowles, R. O. Reid, *Proc. Intl. Symp. on Tusnamis and Tsunami Research*, East-West Press, Honolulu, Hawaii, 1970.
Tsunami Response on Wake Island: Comparison of the Hydraulic and Numerical Approaches, A. C. Vastano, R. O. Reid, *J. Mar. Res.* **28,** 2, Sept. 1970.
The Detection of Secondary Tsunamis, T. C. Royer, R. O. Reid, *Tellus* **2,** 2, pp. 136-142, 1971.
Characteristics of Gravity Waves of Permanent Form, J. J. von Schwind, R. O. Reid, *J. Geophys. Res.* **77,** 3, Jan. 1972.
Gravity Waves in a Rotating Basin–Normal Modes, T. C. Royer, R. O. Reid, *Coastal Engrg. Res. Ctr., Dept. of the Army, Ref. 66-27T*, Texas A & M Univ., Dec. 1966.

173-07720-870-70

NUMERICAL STUDIES OF THE DISPERSAL OF A DENSE EFFLUENT FROM A DESALINATION PLANT

(*b*) Dow Chemical Company.
(*c*) Professor R. O. Reid.
(*d*) Applied research.
(*e*) Determine the concentration along the axis of a plume of dense effluent which is discharged at general angle of elevation into a moving stream and also to find the configuration of the plume axis and its boundaries.
(*f*) Completed.
(*g*) Two distinct regimes of the plume of dense effluent discharged into a steady stream from a sustained source have been studied–the near field problem in which the velocity of the effluent is significantly different from that of the ambient fluid, and the far field problem where the effluent essentially moves longitudinally with the fluid but is still subject to lateral spreading by diffusion and gravity. The near field problem has been studied via a similarity model and compared with flume data provided by the U.S. Army Waterways Experiment Station. The far field problem has been studied via a two-dimensional numerical model which involves a prediction of the longitudinal component of the fluid vorticity as well as the effluent concentration at successive cross-sections downstream from the apex of the plume.
(*h*) **A Numerical Model of the Dispersion of a Dense Effluent in a Stream,** H. Crew, *Texas A & M Res. Foundation Proj. 716 Tech. Rept. 70-10T*, 156 pages, June 1970.
Numerical Simulation of the Dispersion of a Dense Jet Discharged into a Homogeneous Stream, R. O. Reid, T. M. Mitchell, Final Rept. to Dow Chemical Company. To appear as part of a larger report to the Office of Saline Water from Dow Chemical Company.

UNIVERSITY OF TEXAS AT AUSTIN, College of Engineering, Department of Civil Engineering, Austin, Tex. 78712. Dr. Walter L. Moore.

174-02162-810-30

HYDROLOGIC STUDIES, WALLER CREEK WATERSHED

(*b*) Cooperative with U.S. Geological Survey.
(*d*) Field investigation; applied research.
(*e*) Measurements of rainfall and runoff for a 4-square mile and a 2-square mile portion of the Waller Creek watershed are being made to provide basic information for estimating runoff from small urban watersheds in the Southwest area. Two stream flow stations and a rain gage net are in operation. Studies of the correlation between runoff, rainfall, and the characteristics of the drainage basin are being made by various proposed methods to serve as a base comparison with the data as it is collected.
(*g*) Data has been collected since 1956 by the U.S.G.S. and for later years is available in special reports listed below. Data has been used in a number of hydrologic studies and its use will continue.
(*h*) **Compilation of Hydrologic Data, Waller and Wilbarger Creeks, Colorado River Basin, Texas 1966,** Geological Survey, Water Resources Division, Austin, Tex.

174-05456-810-00

MATHEMATICAL MODELS FOR RELATING RUNOFF TO RAINFALL

(*d*) Master's and Doctoral research based on computer analysis and field data.
(*e*) Using the Stanford Watershed Model as a starting point a revised general procedure for a numerical simulation of watershed hydrology was developed with an effort to provide more realistic simulation of infiltration and soil moisture movement. Also work was done on using the Stanford Watershed Model to investigate its use as a means for determining the effect of watershed changes on the streamflow.
(*g*) The translation of the Stanford Watershed was used successfully for a number of purposes and the revised simulation procedure has been completed and a few limited applications made. The results appear promising.
(*h*) **Numerical Simulation of Watershed Hydrology,** in *Systems Approach to Hydrology, Proc. Bi-Lateral Seminar on Hydrology*, Water Resources Publications, Ft. Collins, Colo., 1971.
Numerical Simulation of Watersheds Using Physical Soil Parameters, *Proc. 13th Cong. Intl. Assoc. Hydraul. Res.* **1,** pp. 211-220, Aug.-Sept. 1969.

174-05457-360-60

A NEW TYPE ENERGY DISSIPATOR FOR CULVERT OUTLETS

(*b*) Texas Highway Dept. and U.S. Bureau of Public Roads.
(*d*) Experimental and theoretical thesis work.
(*e*) Study of a culvert energy dissipator based on the use of a sector of a circular hydraulic jump. Apparent advantages of the device are the stability of the jump over a range of discharge and tailwater conditions and the opportunity to spread the culvert discharge back to the original stream width. Problems of practical geometry have been explored and initial designs developed for a structure that performs well for a considerable range of tailwater conditions. The structure is adaptable for use either at the outlet of a box culvert or a circular pipe culvert.
(*h*) **Design Aspects and Performance Characteristics of Radial Flow Energy Dissipators,** W. L. Moore, K. Meshgin, *Research Report 116-2F*, Center for Highway Res., Aug. 1970.

174-05459-420-00

FINITE-AMPLITUDE GRAVITY WAVES

(*c*) Dr. L. R. Mack, Dept. of Engrg. Mechanics.
(*d*) Theoretical; basic research.
(*e*) Our previously published treatment breaks down for very small values of the depth-to-wave-length ratio; this breakdown is now recognized as a singular perturbation problem. Appropriate stretching of the vertical coordinate and the depth parameter facilitates use of the method of matched asymptotic expansions to obtain a valid solution for small depth. Velocity, surface configuration, and frequency of oscillation are being obtained.

174-05953-870-36

MIXING AND DISPERSION OF CONTAMINANTS IN RESERVOIRS

(*c*) Dr. Frank D. Masch.
(*d*) Basic and applied research; field investigation.
(*e*) Study of the mixing and dispersion of contaminants in inland fresh waters. The study includes an investigation of the effects of currents, turbulent wave action, and periodic overturning on the disposition of waste materials discharged into reservoirs and lakes. The stability effects of temperature and density gradients within the receiving waters are also being determined. Mixing processes in both deep and shallow water reservoirs are being studied in the field.
(*h*) **Macro-Turbulence from Wind Waves,** C. Y. Lee, F. D. Masch, Tech. Rept. to the Federal Water Pollution Control Admin., Hydraulic Engrg. Lab., Univ. of Texas at Austin, *Tech. Rept. HYD 10-6903, CRWR-47*, July 1969, 146 pp.
Analysis and Prediction of Conservative Mass Transport in Impoundments, A. J. D'Arezzo, F. D. Masch, Tech. Rept. to the Environmental Protection Agency, Hydraulic Engrg. Lab., Univ. of Texas at Austin, *Tech. Rept. HYD 10-7004, CRWR-73*, Dec. 1970, 367 pages.
Macro-Turbulence from Wind Waves, C. Y. Lee, F. D. Masch, *Proc. 12th Coastal Engrg. Conf., ASCE* **1,** Chap. 14, Sept. 1970, pp. 223-242.

174-05955-370-60

PERFORMANCE OF CIRCULAR CULVERTS ON STEEP GRADES

(*b*) Texas Highway Department.
(*c*) Dr. Frank D. Masch.
(*d*) Experimental and theoretical research.
(*e*) Study of the behavior of the hydraulic jump in circular broken-back culverts. Of particular concern are the conditions under which a jump will form in the culvert, and with methods to insure that the jump forms in the culvert.
(*h*) **Performance of Single and Double Sills for Steep Circular Culverts,** M. V. P. Rao, R. J. Brandes, Tech. Rept. to Office of Water Resources Research, Hydraulic Engrg. Lab., *Tech. Rept. HYD 12-7102*, Aug. 1971, 102 pages.

174-06180-440-73

TEMPERATURE FIELDS IN STRATIFIED RESERVOIRS

(*b*) Texas Electric Service Company.
(*d*) Applied research; laboratory investigation.
(*e*) The temperature and velocity field in a stratified reservoir has been studied by use of a generalized laboratory model, 8 ft. long, 1 ft. wide, and 2 ft. deep. In the laboratory model factors may be varied; such as the temperature and amount of heated inflow, location of inflow, location of outflow, heat input through surface radiation, and wind shear at the surface. The temperature field and its change with time was measured by 100 thermistors located at selected points throughout the model. The velocity patterns were measured by observing and photographing the motion of dye streaks. The results indicate a thermocline development generally as expected by a reversing flow direction in alternate layers which appears to be related to multiple jets observed by others in experiments with continuously stratified flow and in axially directed flow in a rotating fluid.
(*h*) **A Laboratory Investigation of Temperature and Velocity Fields in a Vertical Section Through a Circulating Cooling Reservoir,** *Tech. Rept. HYD 17-7201*, Hydraulic Engrg. Lab., Feb. 1972.

174-06182-400-33

DISPERSION IN SHALLOW ESTUARIES OF IRREGULAR SHAPE

(*b*) Office of Water Resources Research.
(*c*) Dr. Frank D. Masch.
(*d*) Analytical and experimental research.
(*e*) This research involves the development and verification of a numerical model to evaluate transport characteristics in shallow vertically mixed estuaries of arbitrary shape. The model is designed to assist in developing water quality requirements and assimilative capabilities of estuaries typical of those found along the Gulf Coast of the United States. The study includes adaptation of an existing numerical model of the two-dimensional, time-dependent convective dispersion equation and the evaluation of dispersion coefficients from graphical and analytical considerations of the scale of turbulence and circulation in the estuary.

517-020 O-LT - 74 - 9

(*h*) **Tidal Hydrodynamic Simulation in Shallow Estuaries,** F. D. Masch, R. J. Brandes, *Tech. Rept. HYD 12-7102*, Hydraulic Engrg. Lab., Univ. of Texas at Austin, Aug. 1971, 102 pages.
A Slowly-Varying Conservative Transport Model for Shallow Estuaries, R. J. Brandes, F. D. Masch, *Tech. Rept. HYD 12-7103*, Hydraulic Engrg. Lab., Univ. of Texas at Austin, Aug. 1971, 171 pages.
A Short-Term Conservative Transport Model for Shallow Estuaries, M. Narayanan, R. J. Brandes, F. D. Masch, *Tech. Rept. to Office of Water Resources Research*, Hydraulic Engrg. Lab., Aug. 1971, 90 pages.

174-06183-400-33

RELATION OF PASSES TO PHYSICAL EXCHANGE OF SALINITY IN ESTUARIES

(*b*) Office of Water Resources Research and Texas Water Development Board.
(*c*) Dr. Frank D. Masch.
(*d*) Experimental and theoretical research.
(*e*) Most of the estuaries along the Texas Gulf Coast are separated from the Gulf of Mexico by a long thin chain of offshore or barrier islands. The exchange between gulf and bay waters takes place through a few natural and artificial passes through the barrier islands. It is the principle objective of this proposed project to determine whether the physical exchange of waters between the bays and gulf can be increased by either dredging new passes, or by enlarging existing passes through the barrier islands. In particular, the effect of modifications or additions of passes on the volume of physical exchange, the degree of mixing, and on salinity gradients is to be determined.
(*h*) **Influence of Tidal Inlets on Salinity and Related Phenomena in Estuaries,** N. J. Shankar, F. D. Masch, *Tech. Rept. HYD 16-7001*, *CRWR-49*, Mar. 1970, 107 pages.

174-07722-000-00

LAMINAR FLOW BETWEEN ROTATING CONCENTRIC SPHERES WITH HEAT TRANSFER

(*c*) Dr. L. R. Mack, Dept. of Engrg. Mechanics.
(*d*) Theoretical; basic research.
(*e*) Velocity and temperature fields of viscous fluid enclosed between two coaxially rotating concentric spheres of different temperatures. Solution completed for case of inner sphere having nonuniform temperature.
(*h*) **Thermal Effects on Slow Viscous Flow Between Rotating Concentric Spheres,** T. A. Riley, L. R. Mack, *Intl. J. Nonlinear Mechanics*, 1972, in press.

174-08313-860-33

OPTIMAL OPERATION OF A COMPLEX URBAN WATER SYSTEM

(*b*) Office of Water Resources Research.
(*c*) Dr. Walter L. Moore and W. S. Butcher (Office of Science and Technology, Executive Office of the President, Washington, D.C.)
(*d*) Theoretical and field investigation; applied research, Ph.D. dissertation.
(*e*) Conjunctive operation of ground and surface waters offers considerable economies by regarding the water supply as a system. This project will examine the opportunities for conjunctive operation, using the San Antonio system as an example, and develop optimum operating procedures for this conjunctive system which will consist of ground and surface water and possibly, include, if appropriate, use of surplus storm runoff and possible substitution of wastewaters for other waters. This optimal operation study will explore the use of the various tools of systems analysis for this particular problem. Stochastic dynamic programming, linear programming, and simulation, all will be considered; and the optimal operating policy will be developed using one or more of these techniques.

174-08314-430-00

FLOATING BREAKWATER DESIGN

(*c*) Dr. Walter L. Moore.
(*d*) Experimental; applied research; Master's or Doctoral thesis.
(*e*) Active investigation was started in 1970 of a new concept for a floating breakwater. The breakwater minimizes the required anchoring forces and the amplitude of the transmitted wave by causing the wave forces on different parts of the structure to balance one another. Two sets of reflecting surfaces are arranged so the offset between them can be adjusted to approximately one-half wave length for the range of incident waves anticipated at the site. Tests have indicated good performance in monochromatic waves, and preliminary results in wind generated waves look promising. A patent on the invention has been applied for.
(*h*) **Performance of a Mobile Breakwater that Balances Wave Forces Internally,** *M.S. Thesis*, C. D. Sabathier, Aug. 1971.

UNITED AIRCRAFT CORPORATION RESEARCH LABORATORIES, 400 Main Street, East Hartford, Conn. 06108. Dr R. G. Meyerand, Jr.

175-08315-000-00

NUMERICAL STUDY OF SEPARATION BUBBLES

(*c*) Dr. W. R. Briley.
(*d*) Theoretical; applied research.
(*e*) Computations of the flow field in the vicinity of two-dimensional laminar, transitional and turbulent separation bubbles are being made using an implicit finite-difference method for solving the incompressible, time-dependent, Navier-Stokes equation. The turbulence model being used is based on an integral form of the time-dependent turbulence kinetic energy equation and is applicable in transitional as well as fully-turbulent flow. The purpose of the study is, in part, to determine the limitations of boundary layer theory and to evaluate turbulence models for use in the Navier-Stokes equation.
(*g*) The numerical computations have been shown to proceed smoothly through separation without any evidence of the singular behavior found in solutions to the boundary layer equations at a separation point. The computations provide evidence that the absence of singular behavior is accompanied by a small but noticeable amount of upstream influence associated with separation. Comparisons of computed transitional separation bubbles with experiment have indicated that a turbulence model based on the turbulence kinetic energy equation and developed for use in computing boundary layer flow is adequate for computing small separation bubbles on airfoils.
(*h*) **Numerical Study of Laminar Separation Bubbles Using the Navier-Stokes Equations,** W. R. Briley, *J. Fluid Mechanics* **47**, 4, pp. 713-736, 1971.

175-08316-210-00

COMPUTATIONS OF TURBULENT, SWIRLING FLOWS IN AXISYMMETRIC DUCTS

(*c*) Dr. Olof Anderson.
(*d*) Theoretical; applied re.earch.
(*e*) A finite-difference procedure is being developed for solving the time-averaged equations of motion for incompressible unstalled duct flows in a coordinate system which approximates the streamlines of the flow. The principal feature of the procedure is that compatibility between the inviscid flow and boundary layer is achieved without the need for matching a boundary layer solution to an inviscid flow solution. The availability of this procedure allows optimized duct geometries to be designed for a wide range of applications without having to rely on less generalized empirical design methods.

(*g*) Selected comparisons have been made between results computed using the procedure and experimental data for decelerating flows with inlet swirl and total pressure distortion in both straight-wall and curved-wall ducts. In all cases good agreement has been obtained between the computer results and experiment using a relatively simple turbulence model.

(*h*) **A Comparison of Theory and Experiment for Incompressible, Turbulent, Swirling Flows in Axisymmetric Ducts,** O. L. Anderson, *AIAA Paper No. 72-43*, Jan. 1972.

175-08317-020-00

TURBULENCE MODEL FOR PREASYMPTOTIC FLOWS

(*c*) H. McDonald.

(*d*) Theoretical; applied research.

(*e*) Turbulence models based on the turbulence kinetic energy equation are being developed for use in finite-difference procedures for solving both the time-averaged boundary layer and Navier-Stokes equations. Primary emphasis is being placed on developing models applicable to flows for which a convenient estimate of the eddy scale cannot be made, such as large recirculation regions and merging boundary layers.

(*g*) A turbulence model applicable for use in computing the behavior of both fully-turbulent and transitional boundary layers has been developed. The model is based on the calculation of a turbulent mixing length at each streamwise station as governed by the turbulence kinetic energy equation and the given free-stream turbulence intensity. A large number of comparisons between predictions using the model and measurements have been made and generally good agreement has been obtained.

(*h*) **Practical Calculations of Transitional Boundary Layers,** H. McDonald, *United Aircraft Res. Lab. Rept. L110887-1*, Mar. 1972.

UTAH STATE UNIVERSITY, College of Engineering, Utah Water Research Laboratory, Logan, Utah 84321. Jay M. Bagley, Laboratory Director.

176-0042W-800-00

STATE WATER PLAN INVESTIGATIONS

For summary, see Water Resources Research Catalog **6**, 6.1012.

176-0132W-860-00

ANALYSIS OF DESALTING PLANTS AS A SOURCE OF SUPPLEMENTAL SAFE YIELD

For summary, see Water Resources Research Catalog **5**, 3.0417.

176-0137W-800-00

APPLICATION OF OPERATIONS RESEARCH TECHNIQUES FOR ALLOCATION OF COLORADO RIVER WATERS IN UTAH

For summary, see Water Resources Research Catalog **5**, 6.0560.

176-0140W-810-00

THE DEVELOPMENT OF SIMULATION MODEL FOR THE BEAR RIVER BASIN

For summary, see Water Resources Research Catalog **5**, 6.0570.

176-0141W-800-00

A STUDY OF THE INTEGRATION OF THE WATER RESOURCES OF THE BEAR, WEBER, AND JORDAN RIVERS IN NORTHERN UTAH

For summary, see Water Resources Research Catalog **6**, 2.1405.

176-0144W-800-00

A STUDY OF WATER INSTITUTIONS IN UTAH AND THEIR INFLUENCE ON THE PLANNING, DEVELOPING, AND MANAGING OF WATER RESOURCES

For summary, see Water Resources Research Catalog **6**, 6.1013.

176-0146W-870-00

EVALUATION OF THE FLOOD RISK FACTOR IN THE DESIGN OF STORM DRAINAGE SYSTEMS FOR URBAN AREAS

For summary, see Water Resources Research Catalog **6**, 8.0491.

176-0147W-810-00

REGIONAL ANALYSIS OF RUNOFF CHARACTERISTICS OF SMALL URBAN WATERSHEDS

For summary, see Water Resources Research Catalog **6**, 2.1406.

176-0173W-800-00

INTERREGIONAL PLANNING OF WATER RESOURCES ALLOCATION; A SYSTEMS ANALYSIS APPROACH

For summary, see Water Resources Research Catalog **6**, 6.1009.

The following projects are reported as titles only. Details are to be found in the Water Resources Research Catalog **7**.

176-0174W-700-00

MEASUREMENT OF SOIL MOISTURE BY ATTENUATION OF RADIO FREQUENCY WAVES

176-0175W-810-00

HYBRID COMPUTER SIMULATION OF THE HYDROLOGIC-SALINITY FLOW SYSTEM WITHIN THE BEAR RIVER BASIN

176-0176W-870-00

EFFECTS OF WATER TEMPERATURE INCREASE ON TOXICITY OF WASTE DISCHARGES

176-0178W-800-00

A STUDY OF THE EFFECTIVENESS OF WATER RESOURCES PLANNING GROUPS

176-0179W-800-00

DEVELOPMENT OF TECHNIQUES FOR ESTIMATING THE BENEFITS OF WATER RESOURCES DEVELOPMENT IN ACHIEVING NATIONAL AND REGIONAL SOCIAL GOALS

176-0180W-870-00

BIOLOGICAL EFFECTS ON INTERCHANGE OF METALS AND OF NUTRIENTS BETWEEN SEDIMENTS AND WATER

176-0181W-800-00

A STUDY OF ALTERNATIVE METHODS TO MODERNIZE WATER INSTITUTIONS AND ELIMINATE PROBLEMS

OF MULTIPLE JURISDICTION AND CONFLICTING OBJECTIVES

176-0182W-800-00

EVALUATING WATER REUSE ALTERNATIVES IN WATER RESOURCE PLANNING

176-05750-800-31

ATMOSPHERIC WATER RESOURCES IN UTAH

(*b*) U.S. Bureau of Reclamation.
(*c*) Dr. Charles F. Chappell.
(*d*) Primarily experimental, dependent upon field investigations; basic and applied research.
(*e*) Cloud seeding experiments are in progress to determine the feasibility of increasing water supplies. The investigation includes the operation of a telemetering precipitation measurement system, meteorological and hydrologic observing systems and statistical evaluations.
(*g*) Cloud seeding effectiveness appears to depend upon cloud temperatures with substantial increase observed for the warmer supercooled orographic clouds.
(*h*) **Development of Cold Cloud Seeding Technology for Use in Precipitation Management,** C. F. Chappell, J. E. Fletcher, G. W. Reynolds, Utah Water Research Lab., Utah State Univ., June, 1971.

176-07727-810-06

THEORETICAL STUDY OF INFILTRATION INTO RANGE AND FOREST SOILS

(*b*) Forest Service, U.S. Dept. of Agriculture.
(*c*) Joel E. Fletcher, Professor of Hydrology.
(*d*) Largely theoretical but tied to experimental data.
(*e*) Infiltration curves and soil properties for a number of field soils are being compared to several theoretically derived equations in order to test their compliance to actual measurements.
(*f*) Completed.
(*g*) Infiltration–time curves as computed from rainfall–runoff relations in the field were compared to those computed from such parameters as wettability, soil moisture, particle size distribution and compaction. Agreement between the estimate was satisfactory for most uses.
(*h*) **A Theoretical Study of Infiltration into Range and Forest Soils,** J. E. Fletcher, Y. Z. El Shafei, Utah Water Research Lab., *PRWG60-1*, 1971, Logan, Utah.

176-07729-040-54

INVERSE SOLUTION TO THREE-DIMENSIONAL FLOWS

(*b*) National Science Foundation.
(*c*) Roland W. Jeppson, Assoc. Professor.
(*d*) Theoretical applied research.
(*e*) Methods for obtaining numerical solutions to three-dimensional, inviscid, incompressible fluid flows and free surface Darcian flows in porous media are developed. The formulation of the mathematical problem considers the magnitudes of the cartesian coordinates x, y and z as the dependent variables and the potential function and two mutually orthogonal stream functions as the independent variables. In this inverse space irregular boundaries or free surfaces whose positions are unknown *a priori* in the physical space, become plane of known positions. The resulting boundary value problem is solved by utilizing finite differences.
(*f*) Completed.
(*h*) **Inverse Solutions to Three-Dimensional Free Surface Potential Flows,** *PRWG83-1*, Utah Water Research Lab., Utah State Univ., Logan, Utah, May 1971.
Inverse Solution to Three-Dimensional Flows, *J. Engrg. Mech. Div.*, ASCE.

176-07730-810-05

WATERSHED INFILTRATION AND THE RESULTING FLOW SYSTEM

(*b*) Agricultural Research Service–Cooperative Agreement.
(*c*) Roland W. Jeppson, Assoc. Professor.
(*d*) Basic-applied research.
(*e*) Infiltration characteristics of watershed soils are being studied by formulating initial value and boundary value problems with partial differential equations which result by considering fundamental soil properties and their influence on the unsaturated-saturated soil water flow system.
(*h*) **Theoretical and Experimental Aspects of Watershed Infiltration in Terms of Basic Soil Properties,** *CSC 6810-1*, Computer Sciences Corp., Richland, Wash., Utah Water Research Lab., Utah State Univ., Oct. 1968.
Numerical Solution of the Steady-State Two-Dimensional Flow System Resulting from Infiltration on a Watershed, *PRWG59c-1*, Utah Water Research Lab., Utah State Univ., Logan, Utah, June 1969.
Transient Flow of Water From Infiltrometers–Formulation of Mathematical Model and Preliminary Numerical Solutions and Analyses of Results, *PRWG59c-2*, Utah Water Research Lab., Utah State Univ., Logan, Utah, June 1970.
Formulation and Solution of Water from an Infiltrometer Using the Kirckholt Transformation, *PRWG59c-3*, Utah Water Research Lab., Utah State Univ., Logan, Utah, July 1970.
Determination of Hydraulic Conductivity Pressure Relationship from Saturation Pressure Data, *PRWG59c-4*, Utah Water Research Lab., Utah State Univ., July 1970.
Solution to Transient Vertical Moisture Movement Based Upon Saturation-Capillary Pressure Data and a Modified Burdine Theory, *PRWG59c-5*, Utah Water Research Lab., Utah State Univ., Oct. 1970.
Finite Difference Solutions of Axisymmetric Infiltration Through Partially Saturated Porous Media, *PRWG59c-6*, Utah Water Research Lab., Utah State Univ., Apr. 1971.
Solution of a Two-Dimensional, Steady-State Watershed Flow System Part I, Description of Mathematical Model, also Part II, Evaluation by Field Data, *Trans. ASAE.*

176-07732-840-33

HYBRID COMPUTER SIMULATION AS APPLIED TO THE MANAGEMENT OF WATER SALINITY WITHIN A HYDROLOGIC SYSTEM

(*b*) Office of Water Resources Research.
(*c*) Dr. J. Paul Riley, Assoc. Professor, and Eugene K. Israelsen, Res. Engineer.
(*d*) Theoretical and experimental; applied research for Ph.D. thesis.
(*e*) Derive, test and refine fundamental relationships relating the hydrologic and salinity flow systems. The hybrid computer will be used to demonstrate the applicability of the hydro-salinity model to salinity management in water resource systems.
(*f*) Completed.
(*h*) **A Computer Model of the Quantity and the Chemical Quality of Return Flow,** J. L. Thomas, J. P. Riley, E. K. Israelsen, Utah Water Research Lab., Utah State Univ., Logan, Utah, June 1971.
A Hybrid Computer Program for Predicting the Chemical Quality of Irrigation Return Flows, J. P. Riley, J. L. Thomas, E. K. Israelsen, presented at the *7th Amer. Water Resources Conf., Washington, D.C., Oct. 1971.*

176-07736-840-00

COMPUTER SIMULATION AS A TECHNIQUE FOR THE MANAGEMENT OF WATER SALINITY WITHIN A RIVER SYSTEM

(*b*) Agricultural Experiment Station, Utah State University.
(*c*) Dr. J. Paul Riley, Assoc. Professor.

(*d*) Theoretical and experimental; applied research for a M.S. thesis and a Ph.D. dissertation.
(*e*) The primary purpose of this project is to develop simulation model of the hydrologic and salinity flow system within the Sevier River drainage of central Utah. The model will be verified using hydrologic and salinity data from the Sevier River basin. The model will then be used for conducting sensitivity studies and for testing various alternatives for the management of the salt load within the system.

176-07737-810-56

DEVELOPING A DETERMINISTIC, DISTRIBUTED NONLINEAR SURFACE-GROUNDWATER MODEL FOR THE ATLANTICO 3 PROJECT, COLOMBIA, SOUTH AMERICA

(*b*) U.S. Agency for International Development.
(*c*) Dr. J. Paul Riley, Assoc. Professor.
(*d*) Theoretical and experimental; applied research for M.S. theses and Ph.D. dissertations.
(*e*) Develop a simulation model of the joint hydrologic-economic system for the project area. The hydrologic model will include detailed definition of groundwater flow in both the unsaturated and saturated zones. The model will then be used to test various management alternatives under diftering conditions of irrigation application rates and vegetative cover (both native and cultivated).
(*h*) **A Hybrid Computer Model of the Hydrologic System Within the Atlantico 3 Area of Colombia, South America,** J. P. Riley, E. K. Israelson, *Progress Report*, Utah Water Res. Laboratory, Utah State Univ., Logan, Utah.

176-07738-200-00

THE RELATION OF DISPERSION TO BOUNDARY ROUGHNESS IN STEEP, ROUGH CHANNELS

(*c*) Gary Z. Watters, Assoc. Prof., Dept. of Civil Engineering.
(*d*) Experimental; basic and applied research; Ph.D. dissertation.
(*e*) Flow in steep rough channels such as mountain streams has not been studied enough in detail. The flow resistance depends not only on boundary roughness, but also slope and depth of flow. This project will be concerned with measuring the dispersive properties of a given flow and relating these properties to the flow resistance. For a stream of known flow resistance, this would provide information on the dispersion. For a stream of unknown flow resistance, the dispersive properties can easily be measured with dye and the flow resistance evaluated.
(*h*) **The Relationship between Channel Formation Flows and the Cross-Sectional Shape, Slope and Bed Material in Large Bed Element Streams,** *Ph.D. Thesis* in preparation.

176-07739-870-61

CIRCULATION IN DENSITY-STRATIFIED WASTE STABILIZATION PONDS

(*b*) Center for Water Resources Research.
(*c*) Gary Z. Watters, Assoc. Prof., Dept. of Civil Engineering.
(*d*) Experimental; basic and applied research for Ph.D. dissertation.
(*e*) Realistic design procedures for the hydraulic behavior of waste stabilization ponds are virtually non-existent. Short-circuiting is known to occur and inefficient treatment in "dead" portions of the pond result in poor waste treatment. In this work a model of the pond was constructed and inflow to the pond was of different density than the pond itself. Circulation patterns were observed and different types of entrance and outlet structures were tried to improve pond circulation characteristics. The result should provide more realistic guidelines for waste stabilization pond design.
(*f*) Completed.
(*h*) **Hydraulics of Waste Stabilization Ponds and its Influence on Treatment Efficiency,** K. A. Mangelson, *Ph.D. Dissertation*, Civil Engrg. Dept., Utah State Univ., Logan, Utah, 1971.
Baffling Schemes to Improve Hydraulic Efficiency of Waste Stabilization Ponds, Don Jensen, *M.S. Thesis*, Civil Engrg. Dept., Utah State Univ., Logan, Utah, 1971.

176-07740-440-61

THE EFFECTS OF WIND ON CIRCULATION AND DISPERSION IN A SHALLOW DENSITY-STRATIFIED POND

(*b*) Center for Water Resources Research.
(*c*) Gary Z. Watters, Assoc. Prof., Civil Engineering Department.
(*d*) Experimental; for Ph.D. dissertation, basic research.
(*e*) The effects of wind on the circulating patterns and the dispersive characteristics in density stratified shallow bodies of water is not well known. In this work a long shallow tank is constructed and filled with a density stratified fluid. Air is then drawn across the surface and the development of two-dimensional circulation patterns is observed. The results should indicate the importance of wind as a factor influencing dispersion in shallow ponds.
(*h*) **Two-Dimensional Wind-Generated Circulation and Dispersion in a Shallow Density-Stratified Body of Water,** *Ph.D. Dissertation*, in preparation, Utah State Univ., Logan, Utah.

176-08318-700-75

PROTOTYPE PARSHALL FLUME TESTS

(*b*) Joseph C. Wolf, Incorporated.
(*c*) Dr. C. L. Chen, Prof. of Civil Engineering.
(*d*) Experimental investigation; development.
(*e*) The 9- and 18-inch Parshall flumes with nonstandard entrance transitions have been calibrated. The general forms of the depth-discharge relationships for both free and submerged flow in such flumes have been developed.
(*f*) Completed.
(*g*) The depth-discharge relationships for 9- and 18-inch Parshall flumes with nonstandard entrance transitions deviated quite significantly at low and high flow rates from those for the standard. The values of the coefficients and exponents adopted in the new empirical formulas depend largely on the throat size of the flume and the slope of the incoming pipe.

176-08319-870-47

URBAN STORM RUNOFF INLET HYDROGRAPH STUDY

(*b*) Federal Highway Administration.
(*c*) Dr. C. L. Chen, Prof. of Civil Engineering.
(*d*) Theoretical, experimental, and field investigations; applied research and development.
(*e*) Project concerned with the disposition of runoff from intense rainstorms on urban highways. The objective is to develop a practical design method for computing inlet hydrographs of surface runoff, with average recurrence intervals of 10, 25, and 50 years, from typical urban highways by a flood routing technique. The research plan also calls for the collection of field data in two selected sites and for conducting a laboratory study of runoff from pervious areas.
(*g*) The most accurate computer model, by using the method of characteristics with an explicit scheme based on the specified grid intervals, is being developed for prediction of runoff from urban highways under moving rainstorms. A 20 ft. by 20 ft. rainstorm simulator and a 20 ft. by 20 ft. test bed which can be tilted upward to a 45 degree angle is under construction. Equipment for recording rainfall, runoff, wind velocity and direction, and ambient temperature, is being installed on two selected interstate highway cross-sections.

176-08320-810-47

RUNOFF ESTIMATES FOR SMALL RURAL WATERSHEDS AND DEVELOPMENT OF SOUND DESIGN METHOD

(*b*) Federal Highway Administration.
(*c*) Joel E. Fletcher, Prof. of Hydrology.
(*d*) Experimental.

(*e*) Methods for forecasting peak runoff rates from small ungaged watersheds are being tested and developed.

176-08321-040-20

THREE-DIMENSIONAL CAVITY RESEARCH

(*b*) General Hydromechanics Research, Office of Naval Research.
(*c*) Roland W. Jeppson, Assoc. Professor.
(*d*) Theoretical.
(*e*) Methods for solving general three-dimensional cavity fluid flows are being investigated. An inverse formulation has been developed which considers the magnitudes of the cartesian coordinates, the dependent variables in a space defined by the potential function, and two orthogonal stream surface functions. This formulation has the advantage that the region of most free surface and cavity flow problems is confined to a parallelepiped region in the inverse space. This approach could provide a practical means for obtaining numerical solutions to problems for which a comparable solution in the physical space would be extremely difficult.
(*h*) **Studies to Develop and Investigate an Inverse Formulation for Numerically Solving Three-Dimensional Free Surface Potential Fluid Flows,** *PRWG96-1*, Utah Water Res. Laboratory, Mar. 1971.

176-08322-210-70

THE BEHAVIOR OF PVC PIPE UNDER THE ACTION OF WATER HAMMER PRESSURE WAVES

(*b*) Johns-Manville.
(*c*) Gary Z. Watters, Assoc. Prof. of Civil Engineering.
(*d*) Experimental.
(*e*) Measurements of transient velocities and pressure due to rapid valve closure in PVC pipe under unburied conditions were obtained. The strains in the pipe walls were also measured and the experimental data used to verify that the classical water hammer theory is applicable to more flexible walled pipes.
(*f*) Completed.
(*h*) **The Behavior of PVC Pipe Under the Action of Water Hammer Pressure Waves,** *PRWG-93*, Utah Water Res. Laboratory, Mar. 1971.

176-08323-210-70

EXPERIMENTAL STUDY OF WATER HAMMER IN BURIED PVC AND PERMASTRAM PIPES

(*b*) Johns-Manville.
(*c*) Roland W. Jeppson, Assoc. Professor.
(*d*) Experimental.
(*e*) Water hammer velocities and pressure increments were measured in PVC and Permastram pipes buried under well-compacted conditions. The influence of compacted fill on water hammer is determined by comparing the water hammer characteristics in buried versus unburied pipes.
(*f*) Completed.
(*h*) **Experimental Study of Water Hammer in Buried PVC and Permastram Pipes,** *PRWG 113-1, Utah Water Res. Laboratory, Mar. 1972.*

176-08324-810-31

A HYDROLOGIC SIMULATION OF THE PROVO RIVER BASIN

(*b*) U.S. Bureau of Reclamation.
(*c*) Dr. J. Paul Riley, Professor.
(*d*) Theoretical and experimental; applied research for M.S. theses and Ph.D. dissertations.
(*e*) Develop a simulation model of the Provo River basin. The hydrologic model will include the surface and groundwater systems. Special submodels have been prepared to consider Utah Lake and to consider water rights in the allocation and distribution of irrigation water.

176-08325-810-33

MODELING THE TOTAL HYDROLOGIC-SOCIOLOGIC FLOW SYSTEM OF URBAN AREAS (formerly 177W)

(*b*) Office of Water Resources Research.
(*c*) Professors Dr. Wade H. Andrews and Dr. J. Paul Riley.
(*d*) Theoretical and experimental; applied research for Ph.D. dissertations and M.S. theses.
(*e*) Develop a quantitative sociologic model and link it to a hydrologic model. This requires the quantitative description of social parameters which are significant in decision and policy making for urban flooding and drainage development within a metropolitan area. The models will be synthesized on a hybrid computer.

176-08326-810-88

COMPUTER SIMULATION OF FOREST WATERSHEDS

(*b*) Conifer Biome.
(*c*) Dr. J. Paul Riley, Professor.
(*d*) Theoretical and experimental; applied research for M.S. theses.
(*e*) Verify a simulation model of a selected forest watershed and determine the relative importance of the various processes within the hydrologic system through sensitivity studies. The model will also be used to demonstrate management techniques for a forest watershed.

176-08327-700-00

DEVELOPMENT OF A PORTABLE DIRECT READING OPEN CHANNEL FLOW MEASURING DEVICE

(*c*) Duard S. Woffinden, Res. Engineer.
(*d*) Experimental, applied research and development.
(*e*) The measurement of flow in natural open channels presents a host of difficulties associated with the streambed and bank. Many open channel flow measurement systems overcome these problems by inserting a measuring structure into the stream to control the cross-section. Others use a laborious point by point measurement of cross-section and velocity for this determination. This project seeks to develop a method to use a known dilution rate to measure the flow.
(*f*) Completed.
(*g*) A procedure was developed to use the dilution method which does not require any sampling or subsequent analysis. The unit sensor is placed in the stream and a direct reading of streamflow is shown on an indicating meter. All necessary computations are accomplished by a small integrated circuit analog computer. The entire system is composed of two basic units, the dilution-injection unit and the measurement and control unit. By utilizing integrated circuits for computation and control the complete system can be carried and used by one man.
(*h*) **A Portable Direct Reading Open Channel Flow Measurement Device,** D. S. Woffinden, C. G. Clyde, presented *Symp. on Flow*, Pittsburgh, Pa., May 1971.

VANDERBILT UNIVERSITY, Environmental and Water Resources Engineering Program, Nashville, Tenn. 37235. Dr. Barry A. Benedict, Program Director and Associate Professor.

177-07441-060-36

TEMPERATURE DISTRIBUTIONS RESULTING FROM COOLING WATER DISCHARGES

(*b*) Environmental Protection Agency.
(*c*) Dr. Frank L. Parker, Professor.
(*d*) Experimental, theoretical; basic, applied research; M.S. and Ph.D. theses.
(*e*) Provide field data on temperature distributions resulting from power plant discharges. In addition, basic laboratory information will be gathered and a review of appropriate theoretical models made.

(*g*) Field data has been gathered in some 15 surveys at various sites on rivers and impounded lakes. Both downstream distributions and upstream wedges have been observed. Bata's theoretical wedge solution has proven very adequate if initial mixing is accounted for by using actual measured temperatures for determining density differences. Data has been used for relating to various proposed mixing zone regulations and for fitting to available diffusion models to obtain values of diffusion coefficients. Present work is continuing to test a number of the most widely used models against this data to evaluate their ranges of utility.

(*h*) **Cooling Water Density Wedges in Streams,** *J. Hydraul. Div., ASCE* **97**, HY10, Oct. 1971, pp. 1639-1652.
Mixing Zones Below Thermal Power Plants, F. L. Parker, B. A. Benedict, E. M. Polk, Jr., *Proc. 1971 Intersociety Energy Conversion Engrg. Conf.*, pp. 722-727.
Dispersion of Thermal Discharges in Bodies of Water, E. M. Polk, Jr., B. A. Benedict, F. L. Parker, *Heat Transfer Aspects of Commercial Power Generation*, ed. by K. L. Adler, J. C. Chen, M. L. Griebenow, *AIChE, Chem. Engrg. Prog. Symp. Series* **67**, 1971, pp. 111-119.

177-07742-060-36

HEATED SURFACE JETS DISCHARGED INTO FLOWING AMBIENT

(*b*) Environmental Protection Agency.
(*c*) Dr. Barry A. Benedict, Assoc. Professor.
(*d*) Theoretical and experimental; applied research.
(*e*) The development of a momentum jet model to describe temperature distributions resulting from power plant discharges, to test the model with field data, and to define basic needed coefficients through laboratory studies.
(*g*) A two-dimensional surface jet model, valid for any angle of jet to ambient flow, has been developed. Two coefficients are needed, a drag coefficient and an entrainment coefficient. Field experience has shown that a value of 0.5 is adequate for the drag coefficient. The entrainment coefficient has been shown to be a function of the velocity ratio and geometry. Geometry effects can be described by both the initial discharge angle and the ratio of ambient flow width to discharge width. Several sets of field data have been obtained in river situations. Added laboratory data has been obtained for cases similar to many lake systems, where ambient velocity is near zero. The model has been fitted to several sets of lake data obtained by other investigators, thereby extending the range of model applicability.
(*h*) **Heated Surface Jet Discharged into a Flowing Ambient Stream,** L. H. Motz, B. A. Benedict, *Water Pollution Control Res. Series, Rept. 16130 FDQ 03/71*, 207 pages.
Surface Jet and Diffusion Models for Heated Discharges, B. A. Benedict, E. M. Polk, Jr., E. L. Yandell, Jr., F. L. Parker, *Proc. 14th Cong. Intl. Assoc. for Hydraulic Research* **1**, Paris, Sept. 1971, Paper A22, pp. 183-190.
Surface Jet Model for Heated Discharges, L. H. Motz, B. A. Benedict, *J. Hydraul. Div., ASCE* **98**, HY1, Jan. 1972, p. 181-199.
Heated Surface Jet Model Applied to Lakes, *Mtg. Preprint 1603*, ASCE Natl. Water Resources Engrg. Mtg., Atlanta, Ga., Jan. 1972, 21 pages.

177-07743-060-36

NEGATIVELY BUOYANT JETS IN A CROSS-FLOW

(*b*) Environmental Protection Agency.
(*c*) Dr. Frank L. Parker, Professor.
(*d*) Experimental, theoretical, applied research; M.S. and Ph.D. theses.
(*e*) Study mixing of negatively buoyant jets discharged from a submerged single port diffuser. The study will include acquisition of laboratory data for varying densimetric Froude numbers, velocity ratios, and jet angles, and verification of the use of positively buoyant jet models to predict dilution, jet half-width, and jet trajectory.
(*g*) Two jet diffusion models have been utilized to predict the trajectory and dilution of a negatively buoyant jet. The two models used were Fan's model for a turbulent buoyant jet in a cross-flow, and Abraham's model of a round buoyant jet in a cross-flow. The models predict the dilution and trajectory of a positively buoyant jet, or a rising jet, and have been modified to account for the sinking effect. The use of a modification of Fan's model involves the selection of two coefficients, which are functions of the densimetric Froude number, F, the velocity ratio, $k = U_{jet}/U_{ambient}$, and the initial angle of discharge, β_o'. Twenty-four experimental investigations were conducted at Vanderbilt University involving different combinations of densimetric Froude number, velocity ratio, and initial angle of discharge. Salt was used as the tracer, yielding a fluid that was denser than the ambient receiving water and facilitated measuring concentration profiles of the jet plume. The value of C_d, the reduced drag coefficient, was chosen as zero for both models since any value of C_d would predict a trajectory whose rise would be less than experimentally observed. Typically for angles of discharge the value of α, the coefficient of entrainment, increased with a decrease in the velocity ratio and with an increase in densimetric Froude number. Additionally, there was a marked decrease in the entrainment coefficient with a decrease in the initial angle of discharge.
(*h*) **Negatively Buoyant Jets in a Cross Flow,** J. L. Anderson, *Ph.D. Dissertation*, Vanderbilt University, May 1972. (Also to appear as a report in the EPA project report series).

177-07744-140-36

HEAT TRANSFER IN FLOWING WATER

(*b*) Environmental Protection Agency.
(*c*) Dr. Peter A. Krenkel, Professor.
(*d*) Experimental; basic and applied research.
(*e*) Study the influence of the intensity of turbulence at the air-water interface on the rate of thermal exchange across this interface. Expected similarity to gas transfer research suggests laboratory scale studies to be conducted in a laboratory flume.
(*f*) Completed.
(*g*) Tests and theoretical development have been completed. It has been demonstrated that the effect of heated additions to a river can be analyzed by use of the natural river temperature, rather than the equilibrium temperature, in calculations.
(*h*) **Heat Transfer in Flowing Streams,** V. Novotny, *Ph.D. Dissertation*, Vanderbilt University, Aug. 1971.

177-08328-860-36

TEMPERATURE INCREASES BELOW DAMS

(*b*) Environmental Protection Agency.
(*c*) Dr. E. L. Thackston, Assoc. Professor.
(*d*) Experimental; basic research; Master's thesis.
(*e*) Study the temperature change process in flowing streams and devise a simple predictive model based on weather data from a standard weather station. Specifically, the warming process will be studied for the discharge of cold hypolimnetic waters through a hydroelectric plant.
(*g*) Several field surveys have been conducted on different river reaches below hydroelectric dams. Boats carrying weather equipment float downstream with the released water and also monitor the increasing water temperature of the parcel of water. Weather data is also monitored at a location on the bank. A simple heat balance model has been developed and analysis of the data is continuing.

177-08329-860-36

EVALUATION OF COMPUTER PROGRAMS FOR TEMPERATURE PREDICTION IN RIVERS AND RESERVOIRS

(*b*) Environmental Protection Agency.
(*c*) Dr. Frank L. Parker, Professor.
(*d*) Theoretical; applied research.

(*e*) Treat the several models most commonly used for reservoir temperature prediction, to organize them into common, readily useable forms, and to test them against common sets of data. Concurrent with these studies will be sensitivity analyses of the various models as to their assumptions and possible data errors.
(*g*) Model computer codes have been gathered, with special emphasis on models from Water Resources Engineers, MIT, Corps of Engineers, and Cornell Aeronautical Laboratory. Testing of the models is proceeding.

177-08330-870-00

STRATEGIES FOR REDUCING COOLING POND SIZE

(*c*) Dr. Barry A. Benedict, Assoc. Professor.
(*d*) Theoretical; applied research; Ph.D. thesis.
(*e*) A stochastic model of equilibrium temperature and heat exchange coefficient is being developed. Once developed, this model will be used as input into a deterministic cooling pond model. Use of this double model approach will allow cooling ponds to be analyzed under transient conditions. The study will seek to derive a design procedure that will result in the most economical hydraulic design.
(*g*) Stochastic modeling of parameters presently underway.

VIRGINIA INSTITUTE OF MARINE SCIENCE, COMMONWEALTH OF VIRGINIA, Department of Physical Oceanography and Hydraulics, Gloucester Point, Va. 23062. Dr. C. S. Fang, Department Head.

178-08331-400-54

FLUX OF MATERIALS AT THE MOUTH OF CHESAPEAKE BAY

(*b*) National Science Foundation (RANN Program).
(*c*) Dr. A. Y. Kuo, Dr. C. S. Fang, E. P. Ruzecki, Dr. M. Bender, Dr. R. Byrne.
(*d*) Field and theoretical; applied research.
(*e*) Studies in the field are directed toward the development and verification of a theoretical model of the Chesapeake Bay mouth as a pulsating jet orifice. These studies include flow measurements and also the determination of total water chemistry, particulate matter, and pelagic biota. Past studies have depicted the general hydrographic conditions in the area. Present studies, which will emphasize both the effects of extreme weather and seasonality, should serve to verify the existence and persistence of large nearshore eddies on the sides of the bay mouth as well as indicating the renewal characteristics there, and the extent to which the bay system acts as a contaminant source for the continental shelf.

178-08332-870-52

FATE OF WASTE HEAT DISCHARGED INTO THE JAMES RIVER ESTUARY BY THE SURRY NUCLEAR POWER STATION AT HOG POINT, SURRY COUNTY, VIRGINIA

(*b*) Atomic Energy Commission.
(*c*) Dr. C. S. Fang, R. Bolus.
(*d*) Field investigation; applied research.
(*e*) Temperature profiles in the vicinity of the mixing zone of the heated water discharge plume are being determined. Deduced thermal patterns will be compared with those obtained from previous model studies under similar wind and flow conditions to evaluate the relevance of model studies for these purposes. The importance of winds on the movement of the thermal effluent is under particular consideration.
(*h*) **The Design of the Monitoring System for the Thermal Effect Study of the Surry Nuclear Power Plant on the James River,** R. L. Bolus, S. N. Chia, C. S. Fang. Special Rept. in *Applied Marine Sci. and Ocean Engrg. No. 16.*
Thermal Effects of the Surry Nuclear Power Plant on the James River, Virginia, Part II. Results of Monitoring Physical Parameters of the Environment Prior to Plant Operation, S. N. Chia, C. S. Fang, R. L. Bolus, W. J. Hargis, Jr. Special Rept. in *Applied Marine Sci. and Ocean Engrg. No. 21.*

178-08333-400-60

MATHEMATICAL MODELS OF THE UPPER YORK SYSTEM

(*b*) Va. Div. of Water Resources, Va. Water Control Board, Va. Inst. of Marine Science.
(*c*) P. V. Hyer, C. S. Fang, E. P. Ruzecki.
(*d*) Model development program for contract.
(*e*) Field data were collected and used in the development of mathematical models for predicting salinity and dissolved oxygen levels.
(*f*) Complete.
(*g*) A time-dependent model for predicting salinity at high water slack over a period of several months was developed and verified. A model for predicting dissolved oxygen on an hourly basis including tidal action was developed and verified.
(*h*) **Hydrography and Hydrodynamics of Virginia Estuaries. II. Studies of the Distribution of Salinity and Dissolved Oxygen in the Upper York System,** P. V. Hyer, C. S. Fang, E. P. Ruzecki, W. J. Hargis, Jr. Special Rept. in *Applied Marine Sci. and Ocean Engrg. No. 13.*
Studies of Distribution of Salinity and Dissolved Oxygen in the York River System, P. Hyer, C. S. Fang, E. P. Ruzecki. Presented at the *7th AWRA Conf.*, Washington, D.C., Oct. 1971.

178-08334-400-36

ESTUARIES MIXING AND TRANSPORT

(*b*) EPA, Va. State Water Control Board, Va. Inst. of Marines Science.
(*c*) C. S. Fang, Bruce Neilson.
(*d*) Field investigation; applied research.
(*e*) Determine how substances introduced into the James River are mixed into the body of water and how they are transported to other points. The primary emphasis of the studies during the summmer of 1972 was the dispersion and diffusion of conservative liquid additions. These processes will be studied by following the "batch" release of the dye, Rhodamine WT. It is believed that for the portion of the James between Richmond and Hopewell (and the Appomattox River too) a one-dimensional approach is appropriate. Dye concentrations will be measured at fixed points as the dye cloud passes upstream and downstream. In addition, samples will be taken from moving boats to investigate lateral variations and to obtain at least one example of concentration variation with distance at a (more or less) fixed time. Other longitudinal distribution curves will be constructed from the data collected at fixed points following the method used by Fischer. The dispersion coefficients will then be calculated by using the "change-of-moment method." For the portion of the estuary from Hopewell to Hampton Roads, it will be necessary to use a two-dimensional approach. The dispersion of batch releases of dye will be measured by having moving boats transect the dye cloud both longitudinally and laterally at specified time intervals. The dispersion coefficient will be calculated from the changing pattern of dye concentration. In addition the dye concentration will be monitored at one or two fixed points to determine the time of passage. In addition to the dye studies, temperature, salintiy, dissolved oxygen, BOD and currents will be measured to model the dissolved oxygen regime. Special attention will be given to the oxygen sag near sources of organic pollution (e.g., below Richmond and Hopewell).

178-08335-870-36

BEHAVIOR OF WASTEWATER-ORIENTED NONCONSERVATIVE SUBSTANCES

(*b*) EPA, Va. State Water Control Board, Va. Inst. of Marine Science.
(*c*) C. S. Fang, Bruce Neilson.
(*d*) Field investigation; applied research.
(*e*) In conjunction with the "mixing and transport" studies, the behavior of nonconservative substances, coliform bacteria in particular, will be investigated. Chlorination at selected sewage treatment plants wil be halted for specified periods of time. Samples will then be collected to determine the spatial and temporal variations of the coliform count. Currents, tidal fluctuations and other data collected in previous and concurrent studies will be used to predict likely geometries of the effluent plume throughout the tidal cycle. Sampling points and frequency of observations will be chosen using these predictions in order to obtain as accurate a picture as possible.

178-08336-400-60

WATER QUALITY MANAGEMENT MODEL FOR JAMES RIVER TIDAL PORTION, VIRGINIA

(*b*) Div. of Water Resources, State Water Control Board, Va. Inst. of Marine Science.
(*c*) C. S. Fang, A. Y. Kuo, P. Hyer.
(*d*) Applied research.
(*e*) In the summer of 1971, a field program was carried out in the tidal James River. Salinity, temperature, dissolved oxygen, biochemical oxygen demand and current speed and direction were measured at nineteen transects. These data are being used to develop and verify water quality and salinity models for the James River.

178-08337-400-60

A MATHEMATICAL MODEL FOR SALINITY INTRUSION

(*b*) Cooperative State Agencies (Div. of Water Resources, State Water Control Board, Va. Inst. of Marine Science).
(*c*) Dr. A. Y. Kuo, Dr. C. S. Fang.
(*d*) Field and theoretical; applied research.
(*e*) One-dimensional mass balance equation for salt was applied to the upper York Estuarine System of Virginia, from transects upstream from the limits of salt intrusion in the Pamunkey and Mattaponi Rivers to a transect four miles downstream from their junction which forms the York River. The equation was solved numerically with an implicit finite difference scheme for each of the three rivers. The three are coupled together with a mass conservation equation for the element of water body bounded by the three confluent transects. Hydrographic and salinity data were collected and analyzed for the development and verification of the model.
(*f*) Completed.
(*g*) The model was verified with salintiy data from slack water runs. In conjunction with the construction of a dam in the North Anna River (a tributary of the Pamunkey River) and a proposed dam in the Pamunkey River, the model was run with various degree of fresh water cut-off at the upstream end to predict the resulting increased salinity intrusion. The primary concern of the increased salinity intrusion is the possible destruction of fresh water marshes which are the spawning and nursery ground for anadromous fishes.
(*h*) **A Mathematical Model for Salinity Intrusion,** submitted to *13th Intl. Coast Engrg. Conference.*

178-08338-400-60

MATHEMATICAL MODELS FOR ESTUARINE WATER QUALITY

(*b*) Cooperative State Agencies (Div. of Water Resources, State Water Control Board, Va. Inst. of Marine Science).
(*c*) Dr. C. S. Fang, Dr. A. Y. Kuo.
(*d*) Field and theoretical; applied research.
(*e*) Hydrographic and water quality data were collected in the upper portion of the Rappahannock estuary, Virginia. The data were analyzed and used for the development and verification of one-dimensional mathematical models.
(*g*) Two mathematical models were developed. One based on the mass balance equations of salt, BOD and DO, with convective velocity including both tidal and non-tidal components. The other model had the convective velocity including non-tidal component only. This permits the time increment of numerical computation being larger than tidal cycle and is more suitable for investigating long-term variation of salinity intrusion.
(*h*) Paper presented at the *53rd AGU Annual Mtg.*, Washington, D.C.

178-08339-400-60

THE LONG-TERM VARIATION OF SALINITY INTRUSION INTO AN ESTUARINE RIVER

(*b*) Cooperative State Agencies (Div. of Water Resources, State Water Control Board, Va. Inst. of Marine Science).
(*c*) Dr. A. Y. Kuo, M. A. Orzech.
(*d*) Theoretical; applied research for a Master's thesis.
(*e*) Objective is a more rigorous development of the longitudinal dispersion coefficient for a long-term salinity model. This model describes the long-term variation of the averaged salinity distribution over a tidal cycle along an estuarine river.
(*g*) Expression for a longitudinal dispersion coefficient, averaged over a tidal cycle, has been obtained to a first order approximation. Comparison with field data is underway.

178-08340-050-54

TWO-DIMENSIONAL JET DISCHARGING INTO AMBIENT FLUID OF UNIFORM VELOCITY

(*b*) National Science Foundation (RANN Program).
(*c*) Dr. A. Y. Kuo, M. Crane.
(*d*) Theoretical; applied research for a Master's thesis.
(*e*) Numerical computation was performed for the flow field induced by a two-dimensional jet discharging into ambient fluid of uniform velocity. The boundary conditions simulate the flow of water from the Chesapeake Bay into the Atlantic Ocean. Coriolis parameter was included in the computation.
(*g*) Steady state flow patterns have been computed for several values of the ratio of jet velocity to ambient velocity.

178-08341-400-33

REPEATABILITY IN AN ESTUARINE HYDRAULIC MODEL

(*b*) Office of Water Resources Research.
(*c*) P. V. Hyer.
(*d*) Experimental study for contract.
(*e*) A study was made using the James River hydraulic model located at the Waterways Experiment Station, Vicksburg, Mississippi, to determine the ability of the model to reach and maintain a quasi-steady salinity distribution under constant conditions of river discharge and tidal action.
(*f*) Complete.
(*g*) After the initial transient period, the salinity distribution at a given location, depth and stage of the tide was not constant ± 0.1 percent but was constant ± 0.5 percent.
(*h*) **Repeatability in an Estuarine Hydraulic Model,** *J. Hydraul. Div., ASCE*, Apr. 1972. VIMS Contribution 418.

178-08342-450-22

NUMERICAL MODELING INVESTIGATION OF FORCES ON CYCLONIC GULF STREAM EDDIES

(*b*) Naval Oceanographic Office.
(*c*) Dr. P. V. Hyer, R. Pickett.
(*d*) Theoretical for thesis.
(*e*) A study of recently observed cyclonic eddies shed from the Gulf Stream is being made in an attempt to explain the movements, and size and shape changes of these eddies.

Mathematical modeling is used to observe the effects of various initial conditions and geophysical parameters on the subsequent motion of an eddy.
(*f*) Complete.
(*g*) Model results yield predicted lifetimes agreeing well with observations. Inertial forces were found to cause a rotation of the eddy, while coriolis force caused a westward drift of the eddy, and the two combined to cause a northward drift of the eddy. The cyclonic eddy was found to shed energy by forming an anticyclonic eddy and, if sufficiently elongated, by fissioning.

178-08343-400-10

HYDROGRAPHIC STUDIES OF CHESAPEAKE BAY–COLLECTION OF HYDROGRAPHIC DATA ON CHESAPEAKE BAY AND TRIBUTARIES

(*b*) U.S. Army Corps of Engineers.
(*c*) Dr. C. S. Fang, E. P. Ruzecki, W. Athearn.
(*d*) Field investigation; basic research.
(*e*) Hydrographic data consisting of measurements of tidal elevation, current velocity, temperature and salinity are being collected from the Virginia waters of Chesapeake Bay and its major tributaries within Virginia, the James, York and Rappahannock Rivers and Pocomoke Sound. The field work is directed toward the verification of the Chesapeake Bay Hydraulic Model being built under the supervision of the Corps of Engineers, Baltimore District, in cooperation with Chesapeake Bay Institute and Chesapeake Biological Laboratory, who are working primarily within the Maryland section of the Bay system.
(*f*) Field data collection should be completed by the end of 1973.
(*g*) Field data for the Rappahannock River and Mobjack Bay have been reduced and tabulated.
(*h*) Preliminary data for tides, temperature and salinity have been tabulated and furnished to the Corps of Engineers.

178-08344-400-60

COMPARISON OF NUMERICAL METHODS FOR THE SOLUTIONS OF THE COMPLETE EQUATION OF UNSTEADY FLOW (DATA COLLECTION AND PROCESSING FOR STATE COOPERATIVE MATHEMATICAL MODEL)

(*b*) Cooperative State Agencies (Div. of Water Resources, State Water Control Board, Va. Inst. of Marine Science).
(*c*) Dr. C. S. Fang, S. N. Wang.
(*d*) Theoretical for thesis.
(*e*) Computer oriented mathematical models for numerical analysis of water movement in estuaries are being developed. They are based on the numerical integration of the complete equations of continuity, momentum, and mass balance for unsteady flow. The equations will be solved by three independent methods, the finite difference method, the finite element method, and MAC method. Identical sets of field data, obtained from summer hydrographical surveys for the James River (or Rappahannock River), will be used for each of the three methods of solution.

178-08345-410-10

STORM EROSION PREDICTION OF VIRGINIA'S ATLANTIC SHORELINE

(*b*) U.S. Army Corps of Engineers.
(*c*) W. Harrison, P. Bullock.
(*d*) Field investigation and theoretical research for thesis.
(*e*) An examination of the feasibility of constructing a statistical model to predict beach erosion using predicted water levels and wind values is being made. Centers around erosion activity at 16 points on the Virginia coast, 6 below Cape Henry, and 9 on the barrier islands. Included is an investigation of the relation between profile stations and characteristics of reactions to similar storm types. Basic prediction equation of form is; $\Delta V = f(U_1, V_1, U_2, V_2, \ldots U_m, V_m, W)_{1\text{-}N}$. ΔV is beach volume change, U, V are wind components, W is water level, 1-N are time lags.
(*f*) Complete.

178-08346-220-54

SEDIMENT TRANSPORT IN LOW ORDER TIDAL MARSH CHANNELS

(*b*) National Science Foundation (RANN Program).
(*c*) Dr. R. J. Byrne, J. Boon.
(*d*) Field investigation for thesis research.
(*e*) Field studies of sediment transport processes via fluid suspension in low-order, tidal marsh channels near Wachapreague, Virginia are being made with the goals of giving specific insight into the distribution patterns of fluid velocity and suspended sediment concentration in time and space; of comparing these distributions with those predicted by theoretical formulations in classical fluid dynamics; of determining hydraulic geometry of marsh channels; and of comprehending marsh channel evolution.

178-08347-400-14

DEVELOPMENT OF THE TURBIDITY MAXIMUM IN A COASTAL PLAIN ESTUARY

(*b*) U.S. Army Research Office–Durham.
(*c*) Dr. M. M. Nichols.
(*d*) Field investigation; basic research.
(*e*) Net transport of water and sediment is being examined through several cross-sections of the Upper Rappahannock River for the purpose of determining how suspended sediment accumulates in the fresh-salt transition of an estuary to form a turbidity maximum. Field measurements are made at mean range of the tide over eight tidal cycles at each station, both at low river inflow (August) and at high river inflow (March). A further purpose is to discover what new time-dependent exchange processes may exist which may also lead to accumulation of suspended sediment.

178-08348-410-20

RESPONSE CHARACTERISTICS OF TIDAL INLETS (THE EFFECT OF HYDRAULIC FORCES AND SEDIMENT SUPPLY)

(*b*) Office of Naval Research.
(*c*) Dr. R. J. Byrne.
(*d*) Field study; basic research.
(*e*) Document the response of inlet configuration to short term variations in hydraulic input and littoral drift and to relate the observed responses to the relative variability of the input processes. Wachapreague Inlet, an inlet within the barrier island complex of Virginia's Eastern Shore, has been selected for the study. Numerical models of inlet flow and field studies of the distribution of bottom shear stress are planned for FY 73.

178-08349-400-60

ESTUARINE COMPUTER MODEL OF SALINITY AND DISSOLVED OXYGEN DISTRIBUTION–RAPPAHANNOCK RIVER (DATA COLLECTION AND PROCESSING FOR STATE COOPERATIVE MATHEMATICAL MODEL)

(*b*) Cooperative State Agencies (Div. of Water Resources, State Water Control Board, Va. Inst. of Marine Science).
(*c*) Dr. C. S. Fang, Dr. P. Hyer, Dr. A. Y. Kuo.
(*d*) Theoretical and field investigation; basic and applied research.
(*e*) Mathematical models for the prediction of salinity distribution and dissolved oxygen concentration in the upper Rappahannock River are being developed. Collection of field data sufficient for the verification of the model is being carried out. To known confidence levels, the one model will be able to predict the high water salinity distribution, given the initial salinity distribution and fresh water runoff; and the other the variation of dissolved oxygen with time, given initial temperature and river discharge conditions and tidal amplitude. The particular reach of the Rappahannock River chosen, between Fredericksburg and a little downstream from Tappahannock, is considered sufficient to establish sump conditions for the system under study and encompass the detectable influences of sanitary and industrial discharges.

(*f*) Complete.
(*h*) Report in preparation.

178-08350-400-48

THE EFFECT OF RUNOFF FROM HURRICANE CAMILLE ON THE CONTINENTAL SHELF WATERS OF THE CHESAPEAKE BIGHT

(*b*) Va. Institute of Marine Science; U.S. Coast Guard.
(*c*) R. B. Elder, J. J. Norcross, E. P. Ruzecki.
(*d*) Field investigation and descriptive study for thesis.
(*e*) Data from two cruises off the mouth of Chesapeake Bay subsequent to the passage of Hurricane Camille (August 1969) are analyzed and compared to earlier data collected on the continental shelf. A description of the distribution and movement of Camille flood waters on the continental shelf is given with an indication of probable reasons for resulting salinity distributions.
(*f*) Inactive.
(*g*) Thesis by R. B. Elder.

178-08351-450-00

CIRCULATION AND MIXING IN THE AREA OF THE VIRGINIA CAPES

(*c*) E. P. Ruzecki, Dr. C. S. Fang, Dr. A. Y. Kuo.
(*d*) Field investigation and theoretical study for thesis.
(*e*) A mathematical model of the coastal sea around Chesapeake Bay entrance and the adjacent continental shelf area which, given wind stress and heat flux on the sea surface, together with some conditions on the bottom and boundaries, should be able to describe the general distribution of currents, temperature and salinity, is being developed. After proving satisfactory the model can be used for oceanographic forecasting, such as invasion of long waves from the ocean, the distribution of pollutants, the effect of dredging and beach erosion.
(*g*) Preliminary field work was carried out in September and October 1971. Results of this work are being used to design further field studies directed towards determining surface velocity fields in the study area.

178-08352-870-00

STUDY OF THE PHYSICAL EFFECTS OF THERMAL DISCHARGES INTO JAMES RIVER BY SURRY NUCLEAR POWER PLANT

(*c*) Dr. C. S. Fang, S. N. Chia.
(*d*) Theoretical for thesis.
(*e*) Two- and three-dimensional mathematical models, based on the river condition and geometry, are being developed to predict the temperature distribution of the Surry County nuclear power plant cooling water discharge plume. Data from three field collection systems–a moving boat system, an *in situ* (tower) system and an over-fly system are used to verify the models. Physical parameters to be evaluated include heat exchange coefficient, equilibrium temperature and cloudiness ratio. Various statistical analyses of the data from the moving boat and tower systems are included in the study to make the data more useful.

178-08353-410-20

INVESTIGATION OF THE WATER TABLE IN A TIDAL BEACH

(*b*) Office of Naval Research, Va. Institute of Marine Science.
(*c*) C. S. Fang, S. N. Wang, W. Harrison.
(*d*) Theoretical and field investigation; basic and applied research.
(*e*) Collect a 30- to 60-day time series of observations of elevations of the water table in a beach, elevations of the local ocean surface, elevations of the foreshore at reference points, the position of the tip of the swash, the breaker height and trough depth, local rainfall, runup characteristics, and atmospheric pressure. Analyze the field data by appropriate time-series computer programs; document the interactions between the water table and the environmental variables that cause it to fluctuate; document the effect of the water table on the stability of the foreshore. Elucidate the characteristics of the damped tide wave in the water table and the mechanism by which it is propagated through the sand prism, and to advance recommendations, if possible, for the control of day-to-day (non-storm) changes in tidal beaches by artificial alteration of beach water tables. For the second year, it is proposed to develop a data-report for the entire time series of observations made at Fort Storm during the previous summer; undertake regression analysis of the relationship between changes in volumes of groundwater and corresponding changes in the volume of foreshore sand; and complete the numerical analysis of the water table data.
(*f*) Complete.
(*h*) **Groundwater Flow in a Sandy Tidal Beach, I. One-Dimensional Finite Element Analysis,** *Water Resources Research* **7**, 5, 1313-1322, 1971.
Groundwater Flow in a Sandy Tidal Beach, 2. Two-Dimensional Finite Element Analysis, *Water Resources Research* **8**, 1, 121-128, 1972.
Investigation of the Water Table in a Tidal Beach, *VIMS Special Rept. 60.*

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VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, College of Engineering, Department of Civil Engineering, Blacksburg, Va. 24061. Dr. H. M. Morris, Department Head.

180-0183W-300-00

NUMERICAL STUDIES OF UNSTEADY FLOW IN THE JAMES RIVER

For summary, see Water Resources Research Catalog **6**, 2.1457.

180-07745-370-82

ENERGY DISSIPATION IN PIPE CULVERTS

(*b*) American Concrete Pipe Association.
(*c*) Dr. J. M. Wiggert, Assoc. Professor.
(*d*) Analytical and experimental; basic and applied research.
(*e*) Studies developed the basic relationships and design criteria governing the action and use of roughness elements in circular pipe culverts flowing part full. The purpose of the roughness elements is to dissipate the kinetic energy of the flow in the barrel of the culvert.
(*f*) Completed.
(*g*) Roughness elements can be used to reduce the kinetic energy of flow on steep slopes by 40 percent. A design criterion and configuration of elements were found.

180-08354-300-00

NUMERICAL SIMULATION OF FLOOD FLOWS SUBJECT TO BANK SEEPAGE

(*c*) Dr. J. M. Wiggert, Assoc. Professor.
(*d*) Analytic, applied research.
(*e*) Study the effect of bank storage and seepage on the flood hydrograph.
(*f*) Completed.
(*h*) **Numerical Simulation of Flood Flows Subject to Bank Seepage,** V. L. Zitta, *Ph.D. Dissertation*, Va. Polytechnic Inst. and State Univ., May 1970.
Flood Routing in Channels with Bank Seepage, V. L. Zitta, J. M. Wiggert, *Water Resources Research* **7**, 5, Oct. 1971.

180-08355-300-60

FLOW ROUTING IN THE JAMES RIVER WITH SPECIAL APPLICATIONS

(*b*) Division of Water Resources, Commonwealth of Virginia.
(*c*) D. N. Contractor, Asst. Professor.
(*d*) Theoretical, applied research, operation.

(*e*) Extension of the technique of numerical flow routing to conditions of very high flows, low flows and effect of a dam.

180-08356-220-00

DETERMINATION OF A UNIT SEDIMENTGRAPH

(*c*) J. M. Wiggert, Assoc. Professor.
(*d*) Experimental and field investigation; applied research, Doctoral thesis.
(*e*) An attempt to determine the sediment flow charcteristics of watersheds and those characteristics that vary with streamflow, rainfall and land use. The significant sediment flows occur during periods of high discharge. The anticipated results should permit assessment of suspended sediment transport.

VIRGINIA POLYTECHNIC INSTITUTE and STATE UNIVERSITY, College of Engineering, Department of Engineering Mechanics, Blacksburg, Va. 24061. Dr. Daniel Frederick, Department Head.

181-08357-480-50

THE MEASUREMENT OF THE GROUND WIND STRUCTURE

(*b*) National Aeronautics and Space Administration.
(*c*) Asst. Professor Henry W. Tieleman.
(*d*) Experimental and theoretical research.
(*e*) Research program concerned with the measurements of the ground winds in the atmospheric boundary layer. Not only mean wind and mean temperature are measured, but also recorded are the three turbulence components and the fluctuating temperature.
(*f*) At the present, areas being developed are sensor system, data acquisition, data processing and analysis, simulation of correlated random processes and wind tunnel vortex studies.
(*h*) **Two Stochastic Models for Simulation of Correlated Random Processes,** M. Hoshiya, H. W. Tieleman, *Va. Polytechnic Inst. and State Univ. Rept. VPI-E-71-9*, June 1971.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, Department of Mechanical Engineering, Blacksburg, Va. 24061. Dr. J. B. Jones, Department Head.

182-07750-010-14

TURBULENCE PROPERTIES IN STRONGLY SKEWED THREE-DIMENSIONAL TURBULENT BOUNDARY LAYERS

(*b*) Army Research Office–Durham.
(*c*) Dr. F. J. Pierce, Professor.
(*d*) Experimental.
(*e*) Hot-wire anemometry techniques are being used to measure turbulence properties in a skewed three-dimensional turbulent boundary layer flow. Detailed measurements of all elements of the stress tensor will be gathered.

182-07751-010-14

NUMERICAL SOLUTIONS TO THREE-DIMENSIONAL TURBULENT BOUNDARY LAYER FLOWS

(*b*) Army Research Office–Durham.
(*c*) Dr. F. J. Pierce, Professor.
(*d*) Analytical, basic research.
(*e*) Two finite difference solution techniques for the full three-dimensional turbulent boundary layer equations have been developed, one a DuFort-Frankel explicit scheme and the other a Crank-Nicholson variation resulting in an implicit set of governing equations which are quasilinear and tridiagonal in form for rapid computer solution.
(*f*) Completed.
(*g*) Predicted flow field details agree very well with the experiments of Johnston and of Hornung and Joubert.
(*h*) **An Explicit Numerical Solution of the Three-Dimensional Incompressible Turbulent Boundary Layer Equations,** J. C. East, Jr., F. J. Pierce, to be published in the *AIAA Journal.*
An Implicit Numerical Solution of the Turbulent Three-Dimensional Incompressible Boundary Layer Equations, F. J. Pierce, W. F. Klinksiek, *Interim Tech. Rept. No. 3, ARO-D Project 6858E*, July 1971; *VPI and SU, College of Engrg. Rept. VPI-E-71-14.*

182-08358-010-00

NUMERICAL SOLUTIONS TO THREE-DIMENSIONAL TURBULENT FLOWS

(*c*) Dr. F. J. Pierce, Professor.
(*d*) Analytical, basic research.
(*e*) Finite difference solution techniques are being developed to predict, at least approximately, separation envelopes or surfaces in three-dimensional turbulent boundary layer type flows. Companion numerical techniques are being studied for application to the flow region beyond or within such separation surfaces.

182-08359-010-14

NUMERICAL SOLUTION TO THE THREE-DIMENSIONAL TURBULENT BOUNDARY LAYER ON A ROTATING SURFACE

(*B*) Army Research Office–Durham.
(*c*) Dr. F. J. Pierce, Professor.
(*d*) Analytical and applied.
(*e*) A modified Crank-Nicholson implicit difference formulation which is based on a mixing length model and which gives a system of quasilinear, tridiagonal difference equations is being used to predict the flow field details on a rotating flat plate. The solution allows calculations directly to the physical bounding wall and makes no assumptions concerning a universal inner law in three-dimensional rotating flows.

182-08360-290-54

SOLUTION OF THE TRANSONIC FLOW REGION IN TRUNCATED CONICAL NOZZLES

(*b*) National Science Foundation.
(*c*) Dr. E. F. Brown, Asst. Professor.
(*d*) Theoretical; basic research for Master's thesis.
(*e*) Work concerned with the flow of a perfect inviscid gas through a conical convergent nozzle operating at supercritical pressure ratios. A theoretical solution was obtained using a time-dependent technique and the position of the sonic line and the value of the discharge coefficient were examined at various values of the pressure ratio. A time-dependent method of characteristics was used to treat the jet-boundary points.
(*f*) Completed.
(*g*) The position of the sonic line and the value of the discharge coefficient showed good agreement with experimental results. The solution showed good convergence properties and the results were obtained in less than a quarter of the computational time required by the only other solution of this type.
(*h*) **A Time-Dependent Solution of Compressible Flow Through a Convergent Conical Nozzle,** H. M. Ozcan, *Master's Thesis*, Mech. Engrg. Dept., Va. Poly. Inst. and State Univ., Aug. 1971.
A Time-Dependent Solution of Mixed Flow Through Convergent Nozzles, E. F. Brown, H. M. Ozcan, *AIAA 5th Fluid and Plasma Dynamics Conf.*, Preprint, June, 1972.

182-08361-600-00

A STUDY OF JET REATTACHMENT IN BI-STABLE FLUIDIC DEVICES

(*c*) Dr. E. F. Brown, Asst. Professor.
(*d*) Experimental; applied research for Master's thesis.

(*e*) The problem of jet interaction in a simplified model of a Corning bistable fluid amplifier was examined. The total pressure profiles and the location of the reattachment point of the supply jet were experimentally determined at several control-jet mass-flow rates. Reasonable agreement between these results and a theoretical prediction of the location of the reattachment point was observed.
(*f*) Completed.
(*g*) An apparent acceleration of the rate of development of the supply jet was observed with increasing control-jet mass-flow rate. Experiments revealed that theoretical prediction of the reattachment point location could be improved if the undeveloped portion of the supply jet and the asymmetrical character of its velocity profile were taken into account.
(*h*) **An Experimental Investigation of the Jet Interaction Effects in a Bistable Fluid Amplifier,** F. C. Belen, Jr., *Master's Thesis*, Mech. Engrg. Dept., Va. Poly. Inst. and State Univ., Aug. 1971.

182-08362-700-70

A SPECTROPHOTOMETER FOR THE MEASUREMENT OF LOCAL DENSITY IN A FLOWING GAS

(*b*) E. I. du Pont de Nemours and Company.
(*c*) Dr. E. F. Brown, Asst. Professor.
(*d*) Experimental; development for Master's thesis.
(*e*) Development of a method for the measurement of air density in a wind tunnel. The technique of infrared absorption spectroscopy will be used and the value of the density will be obtained from the radiation absorbed from a 4.28μ source. Plans include the design of a servo-controlled beam-positioning and read-out system to permit contours of constant density to be automatically drawn by an x-y recorder.

182-08363-030-00

THE INTERACTION OF THE WAKE OF A CYLINDER AND A FLAT-PLATE BOUNDARY LAYER

(*c*) Dr. J. B. Jones, Professor.
(*d*) Experimental; basic research for Doctoral thesis.
(*e*) A basic study is being made of the incompressible flow field 80 and more diameters downstream from a circular cylinder which is located with its axis normal to a flat plate on which a zero-pressure-gradient boundary layer is developing. The cylinder diameter is less than the boundary layer thickness, and the cylinder is essentially infinite in length.

182-08364-600-70

PROBLEMS IN FLUIDICS

(*b*) Corning Glass Works.
(*c*) Dr. R. A. Comparin, Professor; Dr. H. L. Moses, Assoc. Professor.
(*d*) Applied research for Master's thesis.
(*e*) Develop information for the design of fluidic devices and circuits. The current work includes a study of signal transmission in integrated circuits and a study of the effects of power nozzle design in gate performance.

182-08365-010-54

STABILITY ANALYSIS OF DEVELOPING SUPERSONIC CHANNEL FLOW

(*b*) NASA Langley Research Center.
(*c*) Dr. J. W. Leach.
(*d*) Analytical, basic research.
(*e*) The complete linearized stability equations governing transition in the boundary layers at the walls of a two-dimensional channel are solved numerically. Calculations are made to determine the effects of channel wall separation distance, ratio of boundary layer thicknesses, and free stream Mach number on the critical Reynolds number.

182-08366-010-00

NUMERICAL SOLUTION OF THE TURBULENT BOUNDARY LAYER EQUATIONS FOR CORNER FLOW

(*c*) Dr. H. L. Moses, Assoc. Professor.
(*d*) Analytical; basic research for Doctoral thesis.
(*e*) A numerical procedure is being developed to compute the boundary layer along a corner. For the turbulent case, a simple eddy viscosity model is used to account for the shear stress in two directions.

182-08367-550-20

INVESTIGATION OF PRESSURE FLUCTUATIONS AND STALLING CHARACTERISTICS ON ROTATING AXIAL-FLOW COMPRESSOR BLADES

(*b*) Office of Naval Research–Project SQUID.
(*c*) Dr. W. F. O'Brien, Asst. Professor; Dr. H. L. Moses, Assoc. Professor.
(*d*) Experimental.
(*e*) Radio-telemetry techniques are being developed for the transmission of flow property data from the rotating blades of an axial-flow compressor. Of special interest are the blade surface pressure fluctuations under off-design and stall conditions.
(*g*) Surface pressure data have been transmitted from a single transducer on the suction surface of an axial-flow compressor blade. A multi-channel system for simultaneous transmission of six pressure signals is under construction.
(*h*) **Instrumentation for Flow Measurements in Turbomachine Rotors,** W. F. O'Brien, H. L. Moses, *ASME Paper No. 72-GT-55*, presented at the *ASME 17th Ann. Intl. Gas Turbine Conf. and Products Show*, San Francisco, Calif., Mar. 1972.

UNIVERSITY OF VIRGINIA, Department of Aerospace Engineering and Engineering Physics, Charlottesville, Va. 22901. Professor Ralph A. Lowry, Department Chairman.

183-08368-240-50

NUMERICAL METHODOLOGY FOR FLUTTER ANALYSIS AND OPTIMIZATION OF AIRCRAFT STRUCTURES

(*b*) NASA, Office of University Affairs.
(*c*) John Kenneth Haviland, Professor.
(*d*) Theoretical; basic research, applies to several theses.
(*e*) Overall project to develop methods of optimizing wing structures subject to flutter and strength constraints. Part of this effort covers development of the 'downwash/potential' method of calculating aerodynamic forces on oscillating wings. The basic idea is to divide the aerodynamic surface into surface elements of different shape, but conforming to shapes of elements used in the structural analysis. Assuming a velocity potential distribution on each element of unknown magnitude, simultaneous equations are set up relating these values to the known normal flow components at an equal number of collocation points. Solution of these equations gives the velocity potential distribution, from which the generalized forces are calculated.
(*g*) Method is working on rectangular oscillating wings in subsonic compressible flow. Is under development for arbitrary planforms and for interfering out-of-plane wings.

183-08369-030-15

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF COMPRESSIBILITY AND PRESSURE GRADIENT ON THE MAGNUS EFFECT

(*b*) U.S. Army Ballistic Research Laboratory.
(*c*) Ira D. Jacobson, Asst. Professor.
(*d*) Basic research; theoretical and experimental.
(*e*) Develop a theory which can be used to predict the Magnus effect on spinning bodies at an angle of attack and to

verify it experimentally. The basic approach is to treat the problem as a boundary layer stability problem to predict the effects of spin and angle of attack on transition.
(*g*) A new theory for the Magnus effect has been developed for the incompressible case. Work is in progress for the compressible, pressure gradient cases.

183-08370-020-54

AN INVESTIGATION OF TURBULENT SHEAR FLOWS AND TURBULENT DIFFUSION USING A LASER ANEMOMETER

(*b*) National Science Foundation.
(*c*) Jeffrey B. Morton, Asst. Professor.
(*d*) Basic experimental research.
(*e*) Research to advance our basic understanding of inhomogeneous turbulence and the turbulent diffusion process. The laser anemometer is being used to measure two-point statistical properties of a turbulent pipe flow. It is also being used to measure local, instantaneous concentrations of particles in the flow allowing for a systematic investigation of the turbulent diffusion process.
(*g*) Two-point velocity correlation functions have been measured and agree well with available hot-wire data.
(*h*) **Measurements of Two-Point Velocity Correlations in a Pipe Flow Using Laser Anemometers,** J. B. Morton, W. H. Clark, *J. Physics E; Sci. Instr.* 4, p. 809, 1971.

183-08371-060-00

ANALYTICAL CHARACTERIZATION OF TURBIDITY CURRENTS

(*c*) Walter D. Pilkey, Assoc. Professor.
(*d*) Theoretical.
(*e*) Improve the theoretical analyses of ocean turbidity currents. Based on three-dimensional deposition data, the velocity height, erosive power, etc., of a turbidity current is sought.
(*g*) New theory appears satisfactory.

WASHINGTON STATE UNIVERSITY, The R. L. Albrook Hydraulic Laboratory, Pullman, Washington 99163. John F. Orsborn, Laboratory Head.

184-0184W-300-00

FLOOD HYDROGRAPHS FOR UNGAGED STREAMS

For summary, see Water Resources Research Catalog 6, 2.1475.

184-07756-870-61

CONTROLLING THE LOCATION AND DISPERSION OF THERMAL POLLUTING EFFLUENTS

(*b*) State of Washington Water Research Center.
(*c*) Claud C. Lomax, Hydraulic Engineer.
(*d*) Experimental, theoretical, basic research.
(*e*) Evaluate techniques for limiting the spread of a thermal plume and its location. See WRRC 6, 2.1483.
(*f*) Completed.
(*g*) This study and the literature review suggest that the factors controlling dispersion and jet location are turbulence, submergence of the jet, boundary conditions, and jet velocity.
(*h*) **Dispersion of Thermal Effluents,** C. C. Lomax, *Bull. 323*, College of Engrg. Res. Div., Wash. State Univ., 1971.

184-07764-300-00

RIVER ENGINEERING

(*d*) Theoretical; applied research.
(*e*) Analysis of available literature on a variety of river engineering problems including land form-discharge relationships, pipeline crossings, river channel patterns, etc., to develop better river system analytical methods.

184-07767-030-54

EFFECTS OF TURBULENCE ON DRAG OF ANGULAR BLUNT BODIES

(*b*) National Science Foundation.
(*c*) John A. Roberson, Civil Engrg. Professor.
(*d*) Experimental; basic research for M.S. theses.
(*e*) Investigate the effect of turbulence intensity in relation to the coefficient of drag of blunt angular bodies.
(*g*) Original experiments indicated that free-stream turbulence causes a reduction in drag of certain angular bodies such as a cube; however, recent measurements indicate the same free-stream turbulence can significantly increase the drag of other shapes. For example, the drag of spool shapes or beam shapes (oriented with flanges normal to flow direction) exhibit an increase in drag with an increase in free-stream turbulence of about 8 percent.
(*h*) **Turbulence Effect on Drag of Angular Blunt Bodies,** J. A. Roberson, G. Scott Rutherford, *J. Hydraul. Div., Proc. ASCE* 95, HY2, Mar. 1969, pp. 781-785.
The Effects of Turbulence on the Drag of Bodies Having Angular Form, M. Stine, *M.S. Thesis*, Wash. State Univ., Pullman, June 1971.
Effects of Free Stream Turbulence on the Drag Coefficients of Cylinders Having Square and Rectangular Cross Sections, C. Y. Lin, *M.S. Thesis*, Wash. State Univ., Pullman, Sept. 1970.

184-07769-440-65

VANCOUVER LAKE HYDROLOGIC AND HYDROGRAPHIC STUDY

(*b*) Port of Vancouver.
(*d*) Integration of four project phase reports into combined technical reports. Ph.D. thesis on water quality prediction combines field and experimental data into hydrodynamic aquatic life and water quality computer models to predict future lake quality as a function of physical modifications to natural system.
(*e*) See (d). To predict effects of possible improvements on culturally-eutrophic lake through dredging, curtailing pollution and introducing better quality water from Columbia River.
(*g*) **Summary Report: Water Quantity and Quality Studies of Vancouver Lake, Washington,** Sept. 1971.

184-08372-340-73

HYDRAULIC STUDIES OF THE ROCK ISLAND DAM POWERHOUSE ADDITION

(*b*) Public Utility District No. 1 of Chelan County, Washington.
(*c*) Alan F. Babb, Assoc. Hydraulic Engineer.
(*d*) Experimental, applied research, development.
(*e*) A 1:75 scale model is being used to assist in the design of a powerhouse addition at the existing Rock Island Dam on the Columbia River. The objective of the study is to position the powerhouse with special consideration given to passage of anadromous fish by the dam, power output, construction cost, and navigation by the dam.

184-08373-800-60

WATER PLANNING ACTIVITIES IN THE COLUMBIA RIVER BASIN AND WASHINGTON STATE

(*b*) Washington State Department of Ecology.
(*c*) Howard D. Copp, Assoc. Hydraulic Engineer.
(*d*) Survey, operations, applied research.
(*e*) Agency water planning activities were evaluated and planning procedures assessed for current efforts in subject areas. An information retrieval system is in preparation and design of public participation practices are under way. All results will be applied to Washington State Water Plan efforts in forthcoming years.
(*h*) **An Assessment of Water Resource Activities Related to Columbia Basin Waters Within Washington State,** M. Th. Arce', H. D. Coop, J. F. Orsborn, State of Wash. Water Res. Center, Pullman, Wash., June 30, 1970.

Information and Planning for Water Resources Management, H. D. Copp, M. Th. Arce', State of Wash. Water Res. Center, Pullman, Wash., June 1971.

184-08374-120-00

SLURRIES AND NON-NEWTONIAN FLOWS

(*c*) Walter C. Mih, Assoc. Hydraulic Engineer.
(*d*) Theoretical; basic and applied research.
(*e*) Analyze the published frictional loss data on solid-liquid flow in pipes and compile a bibliography on solid-liquid flow in pipelines.
(*g*) Developed a theoretical model to explain the friction loss of solid-liquid suspension flows in pipes of various sizes.
(*h*) **Solid-Liquid Suspension Flow in Pipes,** W. C. Mih, *Proc. Sedimentation Symp. to Honor H. A. Einstein*, Univ. of Calif., Berkeley, June 1971.
Bibliography of Solid-Liquid Transport in Pipelines Including Theoretical Analysis and Research Needs, W. C. Mih, C. K. Chen, J. F. Orsborn, College of Engrg., Wash. State Univ., Pullman, Dec. 1971, 123 pp.

184-08375-210-54

FLOW IN ROUGH CONDUITS

(*b*) National Science Foundation.
(*c*) John A. Roberson, Prof. of Civil Engineering.
(*d*) Experimental and theoretical, basic research for M.S. and Ph.D. theses.
(*e*) By considering the equations governing resistance of a smooth boundary, the drag of roughness elements, the velocity distribution according to Prandtl's mixing length theory and the concentration and size of roughness elements, it is possible to obtain a solution for uniform flow in roughened conduits.
(*g*) The theory has been successfully applied to artificially roughened conduits and is now being tested for naturally rough boundaries.
(*h*) **Flow in Conduits with Low Roughness Concentration,** J. A. Roberson, C. K. Chen, *J. Hydraul. Div., Proc. ASCE* **96,** HY4, Apr. 1970, pp. 941-957.
Surface Resistance of Plane Boundaries Roughened with Discrete Geometric Shapes, J. A. Roberson, *Bulletin 308*, Wash. State Univ., College of Engrg. Res. Div., Pullman, Jan. 1968.
Flow Resistance in Conduits Roughened with Several Sizes of Hemispheres, M. I. Bajwa, *M.S. Thesis*, Wash. State Univ., Pullman, June 1971.
Characteristics of Turbulence and Flow Resistance in Pipes Roughened with Hemispherical Elements, C. K. Chen, *Ph.D. Thesis*, Wash. State Univ., Pullman, Aug. 1970.

184-08376-710-00

FLOW VISUALIZATION BY SOLVENT-LAMPBLACK TECHNIQUE

(*c*) John A. Roberson, Prof. of Civil Engineering.
(*d*) Experimental.
(*e*) A splitter plate used with axisymmetric bodies allows the solvent-lampblack technique to be used to visualize the flow about such bodies.
(*g*) The basic principle is sound; however, refinements are being made to minimize the effects of the splitter plate on the basic flow pattern.

184-08377-030-00

GROUND EFFECTS ON THE DRAG, LIFT AND PITCHING MOMENT OF AN ANGULAR BODY

(*c*) John A. Roberson, Prof. of Civil Engineering.
(*d*) Experimental, basic research for Ph.D. thesis.
(*e*) The effect of the proximity of a floor on the drag, lift and moment of a square cylinder is to be studied. The results should be applicable to underwater structures or to elevated buildings.

184-08378-300-60

ESTABLISHMENT OF LOW FLOW CRITERIA FOR CONSERVATION, RECREATION AND AESTHETIC PURPOSE

(*b*) Dept. of Ecology of the State of Washington.
(*d*) Analytical; applied research.
(*e*) Development of a quick and dependable method for determining natural low flows in Washington rivers, and establishment of minimum water levels in lakes for the purpose of protecting fish, game, recreational or aesthetic values of said public waters. See WRRC 6.1056.
(*g*) Seven-day low flow of two years' recurrence interval can be shown equivalent to basin storage (a sustained component) discharge component of base flow as obtained by Kunkle's method. Correlation of this "slow flow" with some significant geomorphologic parameter of a drainage basin is being sought on regional basis for the whole of Washington State. Similar methodology is also being developed for ungaged basins.

184-08379-830-05

SOUTHWEST WASHINGTON STUDY

(*b*) Soil Conservation Service.
(*c*) Manuel Th. Arce', Assoc. Hydraulic Engineer.
(*d*) Applied research, operation and development.
(*e*) The analysis and operation of a computer system for assembling and displaying land management information. The computer programs prepared by the Soil Conservation Service have been modified and implemented to produce different map types (soils, land use, ownership, etc.) for the Southwest Washington Study.
(*h*) Manual to operate the computer program in preparation.

184-08380-800-60

STORAGE AND INFORMATION RETRIEVAL FOR THE STATE OF WASHINGTON WATER RESOURCES ARCHIVE

(*b*) Washington State Dept. of Ecology.
(*c*) Manuel Th. Arce', Assoc. Hydraulic Engineer.
(*d*) Applied research, operation and development.
(*e*) A High Speed Information and Retrieval System has been tested to store and retrieve abstracts to be prepared from documents in the collection of the State of Washington Water Resources Archive.
(*f*) Completed.
(*h*) **Storage and Information Retrieval System for the State of Washington Water Resources Archive,** Manuel Th. Arce', *Albrook Hydraulic Lab. Rept.*, Wash. State Univ., Pullman, Nov. 1971.

184-08381-310-61

PULLMAN FLOOD PLAIN PILOT STUDY

(*b*) Albrook Hydraulic Lab., Water Research Center, State of Wash. Dept. of Ecology and the U.S. Corps Engineers.
(*d*) Applied and theoretical research.
(*e*) Construct and prove a model showing approximately one mile of downtown Pullman, Washington's flood plain. The study includes testing various alternative solutions to flood problems and documenting the results employing the aid of movies and still photographs for educational purposes.

184-08382-210-70

BUTTERFLY VALVE TORQUE TEST

(*b*) Fabri-Valve.
(*c*) Claud C. Lomax, Hydraulic Engineer.
(*d*) Applied research.
(*g*) Test a 24" butterfly valve for coefficient of velocity and torque at various openings and flow rates. Range of flow up to approximately 45 cfs.

184-08383-810-00

STOCHASTIC ANALYSIS OF FLOOD HYDROGRAPHS

(*c*) Donald L. Bender, Prof. of Civil Engineering.
(*d*) Theoretical, field investigation.
(*e*) Investigate the stochastic characteristics of the transformation function for precipitation-runoff and the resulting hydrographs. A mathematical model to represent the stochastic process of precipitation for selected basins will be developed and samples of long-term precipitation data will be generated. A conceptual model of the instantaneous unit hydrograph will be used for the precipitation-runoff transformation relationship. Attempts will be made to include the nonlinear response of the basin through the input (rainfall excess) rather than through the relationship itself. The response of the basin due to storm variations will be studied for stochastic properties. The hydrograph resulting from the simulation will be analyzed for stochastic characteristics and a method developed to determine flood hydrographs of a given frequency.

184-08384-860-00

THERMAL PROBLEMS IN RESERVOIRS

(*c*) Richard W. Crain, Jr., Assoc. Professor of Mech. Engineering.
(*d*) Theoretical; basic and applied research; operation and development.
(*e*) Research involves the analysis of various types of thermal problems in reservoirs and the development of a systematic method for the solution of such problems.
(*g*) A bulletin has been written which is designed to aid field personnel in the general solution of thermal problems. Future bulletins will be directed toward the application of the methods presented to specific problems.
(*h*) College of Engineering Research Division bulletin in preparation.

184-08385-060-00

EFFLUX FROM A THERMALLY STRATIFIED FLOW

(*c*) Richard W. Crain, Jr., Assoc. Professor of Mech. Engineering.
(*d*) Experimental; applied research; Doctoral thesis.
(*e*) Research involved experimental determination of temperatures and flow rates for withdrawal under a vertical lift gate into a side channel from a thermally stratified flow. Variables included lift gate opening and side channel take-off angle.
(*f*) Completed.
(*g*) An optimum discharge was determined in order to obtain minimum temperatures in the side channel. At low ratios of side channel to main channel flow rates a range of take-off angle provides minimum temperatures, but at flow rate ratios about 30 percent only a 90° take-off angle provides minimum temperatures.
(*h*) College of Engineering Research Division bulletin in preparation.

UNIVERSITY OF WASHINGTON, Department of Civil Engineering, Seattle, Wash. 98195. Professor D. A. Carlson, Department Chairman.

185-07772-060-61

INTERNAL CURRENTS RESULTING FROM INTERMEDIATE DENSITY INFLOWS INTO STRATIFIED RESERVOIRS

(*b*) State of Washington Water Research Center.
(*c*) Professor B. W. Hunt.
(*d*) Experimental; basic and applied research.
(*e*) Laboratory study of the internal currents established by an inflow of intermediate density into a two-layer density-stratified reservoir.
(*f*) Completed.
(*h*) **Internal Currents Resulting from Intermediate Density Inflows into Stratified Reservoirs,** W. F. Rittall, B. W. Hunt, *C. W. Harris Hydraulics Lab. Tech. Rept. 28*, June 1970.

185-07773-070-61

GROUNDWATER SEEPAGE PAST SHARP AND ROUNDED CORNERS

(*b*) State of Washington Water Research Center.
(*c*) Professor B. W. Hunt.
(*d*) Experimental; basic research.
(*e*) The streamline pattern and pressure distribution in the vicinity of a sharp, 270-degree corner is investigated experimentally, and then the effect of gradually rounding this corner is studied. Darcy solutions, obtained with the aid of an electrical analogy, are compared to the experimental results.
(*f*) Completed.
(*h*) **Groundwater Seepage Past Sharp and Rounded Corners,** B. W. Hunt, A. M. Ishaq, *C. W. Harris Hydraulics Lab. Tech. Rept. 30*, July 1971.

185-07774-060-00

UNSTEADY, UNCONFINED SEEPAGE TO A PARTIALLY PENETRATING WELL

(*c*) Professor B. W. Hunt.
(*d*) Theoretical; basic and applied research; Doctoral thesis.
(*e*) A linearized, first order solution is sought for the unsteady, unconfined seepage to a partially penetrating well in an infinitely deep aquifer.
(*f*) Completed.
(*h*) **Unsteady Flow to a Partially Penetrating, Finite-Radius Well in an Unconfined Aquifer,** K. L. Kipp, Jr., *Ph.D. Dissertation* (unpublished), 1971.

185-08386-420-13

WAVE TRANSMISSION CHARACTERISTICS OF FLOATING BREAKWATERS

(*b*) Dept. of the Army, Corps of Engineers, Seattle District.
(*c*) Professor E. P. Richey.
(*d*) Experimental; applied research.
(*e*) Wave transmission characteristics of moored rectangular floating breakwaters are obtained in two-dimensional, regular wave laboratory tests.
(*f*) Completed.
(*h*) **Wave Transmission Tests of Floating Breakwater for Oak Harbor,** R. E. Nece, E. P. Richey, *C. W. Harris Hydraulics Lab. Tech. Rept. 32, Apr. 1972.*

185-08387-450-44

WAVE CLIMATE IN PUGET SOUND

(*b*) Component of a Sea Grant project.
(*c*) Professor E. P. Richey.
(*d*) Field measurement; applied research and development for Master's thesis.
(*e*) Wave spectra are measured at a single site with a 4-probe wave array as dependent upon wind direction and speed. Results are to be examined with the view of using the site for large-scale model testing in a natural wave environment.

185-08388-870-00

FLUSHING CHARACTERISTICS OF SMALL-BOAT MARINAS

(*c*) Professor R. E. Nece, Director, C. W. Harris Hydraulics Laboratory.
(*d*) Experimental, theoretical, and field investigation; applied research; Master's thesis.
(*e*) A study of water circulation and pollutant motions in protected marinas and small boat basins. Field data from existing marinas are to be compared with laboratory tidal model results; limited mathematical models for some flow phenomena are to be developed.

185-08389-850-88

SIMULATED JUVENILE SALMON MIGRATION PAST COOLING-WATER DISCHARGE JET

(*b*) Pacific Northwest Laboratory, Battelle Northwest Institute.
(*c*) Professor R. E. Nece.
(*d*) Experimental; applied research.
(*e*) Laboratory study of a (schematic) model to determine if the hydraulic characteristics of a cooling water discharge jet into a river allow downstream migrating juvenile salmon to enter the relatively undiluted portion of the jet and, if the salmon do enter the jet, to determine where they enter the jet and to estimate their exposure to increased water temperatures.
(*f*) Completed.
(*h*) **Hydraulic Modeling Study: Simulated Juvenile Salmon Migration Past Cooling-Water Discharge Jet,** R. E. Nece, J. C. Kent, *C. W. Harris Hydraulics Lab. Tech. Rept. 31*, July 1971.

185-08390-870-61

NEAR-FIELD TEMPERATURE DISTRIBUTION FOR THERMAL JETS DISCHARGING INTO FLOWING STREAMS

(*b*) State of Washington Water Research Center.
(*c*) Professor R. E. Nece.
(*d*) Experimental; basic and applied research.
(*e*) Laboratory study to determine empirical relationships defining the near-field temperature distribution and jet trajectory for a buoyant, warm-water jet from a circular horizontal nozzle located near the bottom and discharging at right angles to the direction of flow of a relatively shallow unstratified stream. The range of parameters investigated will characterize typical jets of cooling-water being discharged into well-mixed, wide rivers.

185-08391-200-00

OPEN CHANNEL CONTROL BARRIER STUDY

(*c*) Professor H. S. Strausser.
(*d*) Experimental and theoretical; basic research.
(*e*) Laboratory investigation to determine the optimum height and geometry of barriers which may be placed, in subcritical flows, on the floor of a channel for the condition where control is incipient but is just balanced by a preexisting control condition.

UNIVERSITY OF WASHINGTON, College of Fisheries, Fisheries Research Institute, Seattle, Wash. 98195. Robert L. Burgner, Institute Director.

186-06834-850-45

CHUM SALMON SPAWNING CHANNEL

(*b*) U.S. Bureau of Commercial Fisheries (Anadromous Fish Act funds).
(*c*) Dr. E. O. Salo and K. V. Koski.
(*d*) Experimental field investigation; applied and basic research; one Ph.D. thesis project and three Masters theses projects are being supported.
(*e*) An artificial spawning channel for experimental manipulation of environmental and biological factors has been built at the University of Washington field station on Big Beef Creek, Hood Canal. Success of chum salmon fry production and fry quality is being measured in relation to flow, intra-gravel water quality, gravel composition, and spawner density in the natural and controlled environments.
(*g*) Data indicate a strong inverse correlation between the amount of sand in the spawning gravel and the survival to emergence of chum salmon fry. The quality of these fry appears also to be suppressed with the higher amounts of sand. The highest fry production has been obtained from 0.75 females/sq. yd. of gravel, and it may be exceeded. The optimum spawner density in relation to fry quality and survival should be determined within the year.
(*h*) Brief summaries of work are available for the years 1968, 1969, 1970 and 1971. Graduate student theses should be available by January 1973.

186-08392-850-73

ROSS LAKE FISHERY INVESTIGATIONS

(*b*) Seattle City Light.
(*c*) Dr. Robert L. Burgner.
(*d*) Field investigation; applied research.
(*e*) Define the abundance and productivity of game fish populations in Ross Lake reservoir and its U.S. tributaries, their contribution to the recreational fishery, and the possible effects of the proposed increase in the height of Ross Dam and the reservoir on these populations.
(*g*) 1971 population abundance on the basis of tagging and recovery estimates is about 146,000 legal size trout. Age composition and creel census data indicated that combined natural and fishing mortality rates in the present population are quite high. Fishing success in 1971 indicated overall a catch of approximately one fish every two angler-hours on the lake. Observations were made on stream utilization by trout and on stream access and obstructions at present and proposed lake levels. At the higher lake elevation, it is anticipated that Ross Lake fish would adapt by moving upstream in Ross Lake tributaries to spawn successfully. The population has thrived in the elevation rises and fluctuations in the past. Effects of fluctuating lake elevation on fish food production were also studied.
(*h*) Joint Report to Seattle City Light (by Intl. Skagit-Ross Fisheries Committee) in preparation.

186-08393-850-06

APPRAISAL OF EFFECTS OF CURRENT FOREST LAND USES ON FISH HABITAT WITH RECOMMENDATIONS FOR FUTURE STUDY

(*b*) Pacific Northwest Forest and Experiment Station, U.S. Forestry Service.
(*c*) Dr. E. O. Salo, Professor.
(*d*) Intensive review and evaluation of subject in the literature.
(*e*) Prepare a single reference manuscript incorporating annotated bibliography, status report and evaluation of research needs.

186-08394-850-82

REVIEW OF EFFECTS OF LOGGING IN S.E. ALASKA

(*b*) Alaska Loggers Association, Ketchikan, Alaska.
(*c*) Dr. E. O. Salo, Professor.
(*d*) Review and catalog all data, publications, control and investigative programs that pertain to salmon and logging-management in S.E. Alaska. This review to be included in a Ph.D. thesis.
(*e*) Prepare a status report on subject and recommendations for future studies. The report is expected to include a summary review of the status of knowledge and programs that form the basis for the management of salmon and logging in S.E. Alaska.

186-08395-850-82

EFFECTS OF LOGGING STUDY, CLEARWATER RIVER SYSTEM

(*b*) Washington State Dept. of Natural Resources.
(*c*) Dr. E. O. Salo and D. D. Woolridge, College of Fisheries and College of Forest Resources, respectively.
(*d*) Field investigation, applied research.
(*e*) Document the streambed characteristics (i.e., sedimentation and stability) and fisheries resources of Stequaleho Creek in relation to man's land-use activites. The project investigates within the Clearwater drainage the impacts of logging and related practices on the fisheries resource. Specific objectives are to determine the quality of the spawning bed gravel in Stequaleho Creek and the adjacent study sites; determine the streambed stability of Stequaleho Creek and the adjacent study sites; determine

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the sediment concentration in Stequaleho Creek and adjacent study areas in relation to natural and man-caused events; and to determine the relative abundance of salmonids and food organisms (i.e., aquatic insects) in Stequaleho Creek and adjacent study areas.

UNIVERSITY OF WASHINGTON, Department of Oceanography, Seattle, Wash. 98195. Dr. Maurice Rattray, Jr., Department Chairman.

187-07777-300-54

A FIELD INVESTIGATION OF UNSTEADY AND NON-UNIFORM TIDAL AND RIVER FLOW WITH SPECIAL EMPHASIS ON THE TURBULENT STRUCTURE AND ITS CAPABILITY OF TRANSPORTING SEDIMENTS

(*b*) National Science Foundation.
(*c*) Assoc. Professor J. Dungan Smith.
(*d*) Theoretical and field investigations; basic research.
(*e*) Detailed investigation of flow in unsteady and non-uniform turbulent boundary layers in order that accurate boundary pressure and shear stress calculations for known interior flows can be carried out. Also, theoretical and field investigations of erosion and sediment transport by turbulent flow over sand beds.

187-07779-060-26

SHEAR FLOW EFFECTS IN CONSTANT DENSITY AND STRATIFIED FLUIDS

(*b*) Mechanics Division, Air Force Office of Scientific Research.
(*c*) Assoc. Professor William O. Criminale, Jr.
(*d*) Theoretical; basic research.
(*e*) Studies include interaction of shear flow and internal waves; nonlinear development of waves in a two-fluid situation; initial value problems at the thermocline; sea-surface dynamics; turbulence in stratified media; wave breaking; large scale boundary layers.
(*g*) Linearized analysis for all of the above (e).
(*h*) **Disturbance Characteristics in a Plane Jet,** (with G. E. Mattingly, Jr.), *Phys. Fluids* **14,** 11, 2258-2264, 1971.
Structure of the Laminar Boundary Layer in the Presence of a Fluctuating Free-Stream, *Proc. IUTAM Symp. on Unsteady Boundary Layers*, Laval University, Quebec, Canada, May 1971. (Invited Paper).
Stability of an Incompressible Two-Dimensional Symmetric Wake, (with G. E. Mattingly, Jr.), *J. Fluid Mech.* **51,** 2, 223-272, 1972.

187-07780-060-54

INTERNAL WAVES STUDIES

(*b*) National Science Foundation; Office of Naval Research.
(*c*) Prof. M. Rattray, Jr.; L. H. Larsen, Res. Assoc. Prof.; S. Martin, Res. Asst. Professor.
(*d*) Experimental, theoretical, and field investigations; basic research.
(*e*) Studies of internal wave generation, propagation, dissipation and interactions; *in situ* observations of internal waves in the ocean.
(*h*) **Internal Waves,** L. H. Larsen, M. Rattray, Jr., W. Barbee, J. G. Dworski, *Proc. 6th U.S. Navy Symp. on Military Oceanography*, Seattle, May 1969.
Effects of Friction and Surface Tide Angle of Incidence on the Coastal Generation of Internal Tides, J. G. Weigand, H. G. Farmer, S. J. Prinsenberg, M. Rattray, Jr., *J. of Marine Research* **27,** 2, pp. 241-259, 1969.
Resonant Internal Wave Interactions, S. Martin, W. F. Simmons, C. Wunsch, *Nature* **224,** pp. 1014-1016, 1969.
Internal Waves, L. H. Larsen, M. Rattray, Jr., W. Barbee, J. G. Dworski, *Symp. on Physical Variability of the North Atlantic*, Dublin, Ireland, Sept. 1969.
Internal Waves Generation from a Steplike, Constant Slope Continental Shelf, S. J. Prinsenberg, *Ph.D. Dissertation*, Univ. Wash., 134 pp., 1971.
The Excitation of Resonant Triads by Single Internal Waves, S. Martin, W. F. Simmons, C. Wunsch, *J. Fluid Mechanics*, 1972, in press.
Generation and Dissipation of Internal Tides, W. L. Wilmot, *Ph.D. Dissertation*, Univ. of Wash., 129 pp., 1972.
Internal Tides, L. H. Larsen, M. Rattray, Jr., W. Barbee, J. G. Dworski, *Rapports and Proce-Verbaux*, 1972, in press.

187-08396-450-20

EKMAN BOUNDARY LAYER STUDIES

(*b*) Office of Naval Research.
(*c*) Assoc. Professor J. Dungan Smith.
(*d*) Field investigations; basic research.
(*e*) Detailed investigation of the velocity and stress fields found near the upper and lower boundaries of the ocean. During the past two years, emphasis has been placed on spacial and temporal accelerative effects in the Ekman layer under the Arctic ice.

187-08397-450-20

AIDJEX PILOT STUDY SPRING 1972: BOUNDARY LAYER FLOW

(*b*) Office of Naval Research.
(*c*) Assoc. Professor J. Dungan Smith.
(*d*) Field investigations; basic research.
(*e*) Determine the coupling between the ice sheet and water beneath and to outline the mechanics of the friction boundary layer. Effects of both form drag and skin friction are being investigated, and detailed measurements are being made of the turbulent and mean flow fields.
(*h*) **AIDJEX Oceanographic Investigations and 1971 AIDJEX Water Stress Pilot Studies: Introduction,** J. Dungan Smith, *AIDJEX Bull. 4, Jan. 1971; Water Stress Studies*, Arctic Ice Dynamics Joint Experiment, Univ. of Wash., pp. 1-7, 42-43, 1971.
A Report on the 1970 AIDJEX Pilot Study and 1971 AIDJEX Water Stress Pilot Studies: University of Washington Water Stress Studies, L. K. Coachman, J. Dungan Smith, *AIDJEX Bull. 4, Jan. 1971; Water Stress Studies*, Arctic Ice Dynamics Joint Experiment, Univ. of Wash., pp. 8-38, 48-53, 1971.

WEBB INSTITUTE OF NAVAL ARCHITECTURE, Crescent Beach Road, Glen Cove, N.Y. 11542. Edward V. Lewis, Director of Research.

188-05942-520-82

MODEL STUDIES OF SHIP SLAMMING IN WAVES

(*b*) American Bureau of Shipping.
(*c*) Dr. Walter Maclean, Prof. of Engineering.
(*d*) Experimental study making use of ship models in waves; applied research.
(*e*) Two 5-foot models, jointed at amidships for measurement of wave bending moments, were run in waves to determine the conditions for bottom slamming to occur and to compare with theoretical predictions. Relative vertical motion and wave slope along keel were measured. Pressure measurements at one point on bottom were taken.
(*f*) Complete.
(*g*) Fairly good correlation has been obtained between relative vertical velocity at the bow and the occurrence of slamming. However, better correlation is expected when velocity is measured at a point further aft.
(*h*) **Ship Model Study of Incidence of Shipping Water Forward,** D. Hoffman, W. Maclean, *Marine Technology*, April 1970.

188-07781-520-54

EXPERIMENTAL DETERMINATION OF SHIP WAVE RESISTANCE IN MODEL AND FULL SCALE

(*b*) National Science Foundation (Engineering Mechanics Program).
(*c*) Dr. Lawrence W. Ward, Prof. of Engineering.
(*d*) Experimental and theoretical basic research.
(*e*) Development of methods of direct experimental determination of model or ship wave resistance by measurement of the wave pattern, thereby investigating the problems of optimizing hull forms, improving model to full-scale correlation, and devising a technique for determining full-scale ship wave resistance. Includes theoretical work, experimental work in a model tank, and full-scale tests on a boat off the Webb beach. The project has value in providing a hydrodynamic tool of general scientific interest, a method of understanding better the fundamentals of ship resistance, and a means for furthering graduate and undergraduate education.
(*g*) Extensive results are now available to establish the region of validity of longitudinal cut wave surveys on a typical ship model. Results show that errors can be expected in such tests at high Froude numbers in narrow tanks, especially when based on lateral slope data. Analysis of prototype tests run offshore on a boat and corresponding model tests show success in removing the effect of ambient sea signal contamination by means of signal averaging in both cases, and some degree of correlation between the boat and model tests but with an apparent chanelling effect of the model tank sides in the latter tests. Further offshore tests will be necessary to establish the quantitative nature of the correlation.
(*h*) **Wave Resistance Survey From a Longitudinal Cut. Part I: Effect of Probe Location on Model Experiments,** (with R. van Hooff), *Webb Inst. Rept.*, 1972.
Wave Resistance Survey From a Longitudinal Cut. Part II: Correlation of Model Results with a Full-Scale Boat, (with R. van Hooff), *Webb Inst. Rept.*, 1972.

188--8398-520-48

STUDIES OF HIGH FREQUENCY SHIP HULL RESPONSE TO WAVES ("Springing")

(*b*) U.S. Coast Guard.
(*d*) Experimental (model) and theoretical; applied research.
(*e*) Tests with a jointed model, having variable natural frequency of vertical two-noded vibration, in regular waves in a model basin. Magnitude of the vertical bending moment excited at different encounter frequencies, particularly at and near resonance, are measured. Theoretical computer calculations are being made and results compared with experiments.
(*g*) Excellent results have been obtained in tests at various speeds in short waves. Calculations give good agreement in certain cases, but more extensive experimental and theoretical work is needed.
(*h*) Preliminary feasibility study report completed (not yet available).

WESTINGHOUSE ELECTRIC CORPORATION, OCEANIC DIVISION, P.O. Box 1488, Annapolis, Md. 21404.

190-08399-700-00

GAUSSIAN INTEGRATION APPLIED TO ULTRASONIC TECHNIQUE OF VOLUMETRIC FLOW MEASUREMENT

(*c*) S. G. Fisher, Manager, Sonar and Flowmeter Project, MS 9760.
(*d*) Theoretical and experimental applied research.
(*e*) Evaluate the accuracy with which volumetric flow can be determined by summing appropriately weighted measurements derived from transit times of ultrasonic pulses. Transducers are arranged so that the measurements establish mean flow velocity over parallel paths lying in a plane at a known angle to the axis of the conveyance. Path spacings and weighting factors are selected according to the Gaussian technique of numerical integration. A part of the investigation includes the calculation of integration errors for various velocity distributions in pipes of circular or rectangular cross section. Experiments have been conducted to verify the integration error for fully developed turbulent flow in a straight pipe, and to evaluate the errors encountered in installations involving substantial hydraulic complexity which cannot be predicted with high accuracy. The experiments employed a weigh tank facility as a flow measurement standard.
(*g*) The experimental results show that overall accuracy of 0.1 percent in the measurement of fully-developed flow in a straight pipe is achievable when the predicted small error in Gaussian integration is corrected. Tests in the outlet piping of a heat exchanger model indicate an error slightly greater than one percent at the least favorable orientation of the measurement plane. Choosing a better orientation and/or correcting the residual systematic error makes possible overall accuracy well within one percent in this case.
(*h*) **Ultrasonics as a Standard for Volumetric Flow Measurement,** S. G. Fisher, P. G. Spink, *Intl. Conf. on Modern Developments in Flow Measurement*, A.E.R.E., Harwell, Sept., 1971.

UNIVERSITY OF WISCONSIN, College of Engineering, Department of Civil and Environmental Engineering, Madison, Wis. 53706. Professor James R. Villemonte, Department Chairman.

191-03539-700-33

MEASUREMENT OF LIQUID VELOCITY AND TURBULENCE

(*b*) Dept. of the Interior, Office of Water Resources Research.
(*d*) Theoretical and experimental; basic and applied research for M.S. and Ph.D. theses.
(*e*) A three-element probe has been developed to permit the simultaneous observation of two components of the instantaneous near-point velocities in liquid flow in closed ducts using an application of the principle of electromagnetic induction. Reynolds stresses are computed as well as time and space correlations and resulting energy spectra.
(*h*) **Characteristics of Liquid Turbulence in Circular Pipes as Measured by a MHD Probe,** R. L. Gratz, J. R. Villemonte, *ASCE Mtg. on Environmental Engineering*, Chattanooga, Tenn., 1968.
Acquisition and Analysis of Turbulent Water Velocities, R. L. Gratz, J. R. Villemonte, *ASCE Hydraulics Div. Specialty Conf.*, Logan, Utah, 1969.
Application of Magnetohydrodynamics to Measurement of Liquid Velocity and Turbulence, J. R. Villemonte, J. A. Hoopes, H. H. Lettau, *Technical Completion Report*, Water Res. Center, Univ. of Wis., Madison, July 1971.

191-05598-420-44

A STUDY OF GRAVITY WAVES AND THEIR DYNAMIC INTERACTION WITH PILE STRUCTURES

(*b*) Dept. of Commerce, Sea Grant Program; Wisconsin Alumni Research Foundation; Ford Foundation.
(*c*) Dr. P. L. Monkmeyer.
(*d*) Theoretical and experimental; basic and applied research for Ph.D. thesis and M.S. project.
(*e*) Problems in gravity wave analysis under study are development of a single formulation for gravity waves of large-amplitude (i.e., nonlinear waves); examination of the pressure forces on, and the dynamic response of piles and pile groups, subjected to deep-water or intermediate depth waves.
(*g*) A higher order nonlinear theory for symmetrical waves of finite amplitude has been developed.

(*h*) **A Higher Order Theory for Deep Water Waves,** P. L. Monkmeyer, J. E. Kutzbach, *Proc. ASCE Coastal Engrg. Conf.*, Santa Barbara, 1965.
A Higher Order Theory for Symmetrical Gravity Waves, P. L. Monkmeyer, *Proc. 12th Intl. Conf. on Coastal Engrg.*, Washington, D. C., 1970.

191-05790-070-33

DISPERSION AND SALT WATER INTRUSION IN FLOW THROUGH NON-HOMOGENEOUS POROUS MEDIA

(*b*) Dept. of the Interior, Office of Water Resources Research.
(*c*) Dr. J. A. Hoopes.
(*d*) Theoretical and experimental; basic research for Ph.D. thesis.
(*e*) Theoretical description, coupled with experimental confirmation, of the distribution of a conservative pollutant in flow through different patterns of non-homogeneous media is being sought. The purpose of this study is to develop methods for predicting the resulting distribution of a substance introduced into a natural groundwater flow. Theoretical and experimental studies of the distribtuion of salt water in a layered coastal aquifer are also being conducted.
(*f*) Completed.
(*g*) Solutions for the distribution of a dissolved substance in a one-dimensional flow through layered media in various arrangements have been obtained; these solutions compare very well with experimental observations. For salt water intrusion with tidal motion and fresh water flow in a two-layered media, measurements of the time average salinity distribution are in good agreement with the numerical model.
(*h*) **Dispersion and Salt Water Intrusion in Non-Homogeneous Porous Media,** C. S. Tong, *Ph.D. Thesis*, Univ. of Wis., 1971.

191-05791-440-30

CIRCULATION AND MIXING PROCESSES IN LAKES

(*b*) Dept. of the Interior, Office of Water Resources Research.
(*c*) Dr. R. A. Ragotzkie, Dr. J. A. Hoopes.
(*d*) Theoretical, experimental, and field; basic research for M.S. and Ph.D. theses.
(*e*) This investigation deals with field and laboratory model studies of the current and temperature profiles of Lake Superior. These studies are being integrated with mathematical models in an effort to understand and predict motions within the lake and the resulting distribution of substances introduced at various points in the lake.
(*g*) Both frictional and frictionless mathematical models of the large-scale circulation in the Great Lakes (currents and internal waves) have been obtained and compared with observations. A small-scale rotating model of Lake Superior has been constructed.
(*h*) **Large-Scale Motion in the Great Lakes,** G. T. Csanady, *J. Geophys. Res.* **72,** 16, pp. 4151-4162, Aug. 15, 1967.
The Keweenaw Current, A Regular Feature of the Summer Circulation of Lake Superior, R. A. Ragotzkie, *Technical Rept. 29*, Univ. of Wis., Aug. 1966.
A Comparison of Computed and Measured Currents in Lake Superior, N. P. Smith, R. A. Ragotzkie, *Proc. 13th Great Lakes Research Conf.*, 1970.
Investigations of the Circulation of Lake Superior, S. Lien, J. A. Hoopes, *13th Great Lakes Research Conf.*, 1970.

191-06620-050-33

TURBULENCE IN JETS AND STRATIFIED FLOWS

(*b*) Dept. of the Interior, Office of Water Resources Research.
(*c*) Dr. John A. Hoopes and Dr. H. H. Lettau.
(*d*) Theoretical and experimental; basic research for Ph.D. thesis.
(*e*) Theoretical expressions for the mean and turbulent velocity fields for a two-dimensional submerged jet are being developed and tested for a two-dimensional water jet. Turbulent velocities are determined using an electromagnetic probe (see project 03539).
(*f*) Completed.
(*g*) Mean and turbulent velocity measurements are in good agreement with theoretical models and the results of others. From the autocorrelation function, macro and micro length scales and the spectral density function were determined.
(*h*) **Mean and Turbulent Velocities for a Plane Jet,** W. C. Mih, J. A. Hoopes, *J. Hydraulics Div., ASCE*, July 1972.

191-06621-130-82

INFLUENCE OF TURBULENCE ON OIL-WATER SEPARATION

(*b*) American Petroleum Institute.
(*c*) Drs. John A. Hoopes, Dr. L. B. Polkowski, and Dr. W. C. Boyle.
(*d*) Theoretical and experimental; basic research for M.S. and Ph.D. theses.
(*e*) The rates of agglomeration and breakup of oil droplets and the equilibrium droplet sizes are being studied theoretically and in the stationary, turbulent flow field between parallel oscillating plates as a function of droplet concentration and turbulence level. The purpose of this study is to improve secondary oil recovery in oil refinery, waste water, separation basins.
(*g*) Theoretical models of the turbulent structure in oscillating Couette flows were developed and compared with experimental observations.
(*h*) **Turbulent Oscillating Couette Flow and Its Effects on Oil Drops,** R. M. Dave, *Ph.D. Thesis*, Univ. of Wis., 1969.

191-06622-870-73

INDUCED CIRCULATIONS AND DISSIPATION OF HEAT FROM CONDENSER COOLING WATER DISCHARGE

(*b*) Madison Gas and Electric Company, Madison, Wisconsin.
(*c*) Dr. John A. Hoopes.
(*d*) Theoretical, experimental and field; basic and applied research for Ph.D. thesis.
(*e*) Study of heat transfer between jets of warm water, discharged horizontally at the edge of Lake Monona by the Company's cooling water outfalls, and the surrounding lake and atmosphere. The investigation involves field measurements of the velocity and temperature patterns induced by the jets throughout the year, mathematical models of the phenomena, and a laboratory model. The purpose of this study is to define the region of the lake affected by the heat and to consider alternate methods of discharging the warm water to reduce this region.
(*f*) Completed.
(*g*) A mathematical model has been developed which describes the induced circulations and the dilution of the heat by the lake. The model describes the field measurements.
(*h*) **Heated Surface Jets in Steady Crosscurrent,** R. W. Zeller, J. A. Hoopes, G. A. Rohlich, *J. Hydraulics Div., ASCE*, Sept. 1971.

191-06623-210-00

DISTURBED LAMINAR FLOW DUE TO PIPE FITTINGS AND BRANCHES

(*c*) Dr. J. R. Villemonte.
(*d*) Experimental; applied research for Ph.D. thesis.
(*e*) The Reynolds number range is $10<R<30{,}000$ in pipes using oil. The disturbance due to standard type pipe fittings and combined and divided flows in branches is being studied. The objective of the program is to develop design criteria which can be used for estimating energy losses due to fittings operating in the laminar flow regime.
(*f*) Suspended.
(*g*) A type of Moody diagram has been developed for a wide range of pipe fittings and for gate and globe valves which gives the relationship between the fitting friction factor and the Reynolds number for the range given in part (e) above.
(*h*) **Junction Losses in Laminar and Transitional Flows,** D. K. Jamison, J. R. Villemonte, *J. Hydraul. Div., ASCE* **97,**

HY7, Proc. Paper 8258, July 1971. *Ph.D. Thesis* has been completed.

191-06624-440-44

THERMOCLINE DEVELOPMENT IN LAKES

(*b*) Dept. of Commerce, Sea Grant Program.
(*c*) Dr. J. A. Hoopes.
(*d*) Theoretical; basic research for Ph.D. degree.
(*e*) The transient, vertical distribution of temperature in lakes and reservoirs is being studied, using several models for the vertical transport of heat and momentum. The objective of the work is to develop a model for the temperature structure of a lake which describes the location and stability of the thermocline.
(*g*) The thermal energy equation has been solved for the vertical temperature distribution due to a sinusoidal, surface temperature variation, and various surface radiation inputs.

191-06625-440-44

THERMALLY INDUCED MIXING AND OVER-TURNING OF STRATIFIED LAKES AND IMPOUNDMENTS

(*b*) Dept. of Commerce, Sea Grant Program.
(*c*) Dr. John A. Hoopes.
(*d*) Theoretical and experimental; basic research for M.S. and Ph.D. theses.
(*e*) Two mathematical models, describing the flow pattern and the rate of dilution induced by the discharge of a buoyant plume or jet into a stratified lake, are being investigated and tested in a small circular tank and a larger square tank. Empirical relations for the mixing time have been developed. The purpose of this work is to investigate the feasibility of inducing vertical mixing in stratified lakes through the introduction of warm water (power plant or industrial discharge) at the bottom of a lake. A model for predicting the change in stability due to a heated water input at the bottom has been developed.

191-06629-060-36

DYNAMICS OF VISCOUS DENSITY-STRATIFIED FLOW

(*b*) Environmental Protection Agency.
(*c*) Dr. P. L. Monkmeyer.
(*d*) Theoretical and experimental; basic and applied research for Ph.D. thesis.
(*e*) Study is concerned with the two-dimensional flow of a non-diffusive, viscous, density-stratified fluid toward a point sink. The object of the study is the development of expressions for the shape of the expected withdrawal layer and the form of its associated velocity profiles as a function of spatial coordinates, discharge and characteristics of the density-stratified fluid. A laboratory tank has been utilized to test the theoretical expressions. Application of the results of this study to selective withdrawal from surface impoundments for water quality control was considered.
(*g*) Theoretical results have been obtained for the case of a point sink located in the lower corner of a semi-infinite, rectangular flow field. Experimental verification has been satisfactory.
(*h*) **Withdrawal of a Viscous Density-Stratified Fluid From the Bottom of a Reservoir,** S. G. Walesh, *Ph.D. Thesis*, 1969.
Withdrawal of a Viscous Density-Stratified Fluid From the Bottom of a Reservoir, S. G. Walesh, P. L. Monkmeyer, *ASCE Water Resources Engrg. Conf.*, Memphis, Jan. 1970.

191-07782-860-61

A SYSTEMS ANALYSIS OF WATER AND NUTRIENT FLOW IN THE LAKE WINGRA BASIN

(*b*) Wisconsin Water Resources Center.
(*c*) Dr. D. D. Huff.
(*d*) Theoretical and field investigation; applied research.
(*e*) The long-range objective of this research is development of the capability for computer simulation of the cycling and distribution of eutrophic materials.
(*h*) **HTM Program Elements, Control Cards, Input Data Cards,** D. D. Huff, *Eastern Deciduous Forest Biome Memo Rept. 72-13*, Mar. 1972.

191-08608-420-44

LONG WAVE DAMPING BY BUOYANCY-DRIVEN TURBULENCE

(*b*) Dept. of Commerce, Sea Grant Program.
(*c*) Dr. T. Green.
(*d*) Experimental; basic research.
(*e*) The decay of long waves in a fluid in a state of turbulent Benard convection is being measured in a rectangular tank.
(*g*) Results agree with a crude theory. Damping increases by a factor of two or three (due to the turbulence) at Rayleigh numbers near 10^{10}.

191-08609-420-00

WAVE INTERACTION WITH MOVABLE STRUCTURES

(*c*) Dr. T. Green.
(*d*) Theoretical; basic research.
(*e*) Wave transmission and reflection associated with a pure sinusoidal wave incident on a paddle hinged at the channel bottom is studied, using wavemaker theory.

191-08610-420-00

LONG WAVES IN AN ICE-COVERED CHANNEL

(*c*) Dr. T. Green.
(*d*) Theoretical; basic research.
(*e*) Standard long wave equations, with the ice treated as an elastic sheet, are used to obtain the dispersion relation for long waves progressing down an ice-covered channel.

191-08611-070-33

DISPERSION OF SUBSTANCES IN GROUNDWATER FLOW THROUGH ANISOTROPIC POROUS MEDIA

(*b*) Dept. of the Interior, Office of Water Resources Research.
(*c*) Dr. J. A. Hoopes.
(*d*) Theoretical and experimental; basic research for Ph.D. thesis.
(*e*) Investigate the effects of anisotropy on the dispersion of dissolved substances. Experimentally uniform, two-dimensional, anisotropic media are being constructed from sands of different sizes. Dispersion coefficients will be calculated from the spread of a dilute salt tracer and correlated with media and flow properties. The results will be compared with existing models; alternative models will also be studied.

191-08612-440-88

CIRCULATIONS, TEMPERATURE PATTERNS, MATERIAL TRANSPORT AND EXCHANGE IN LAKE WINGRA

(*b*) International Biological Program.
(*c*) Dr. J. A. Hoopes, Dr. P. L. Monkmeyer, Dr. T. Green.
(*d*) Theoretical, experimental and field; basic and applied research for M.S. and Ph.D. theses.
(*e*) Investigate the circulation and mixing processes in the lake as a basis for modeling substance transport and exchange. One- and two-dimensional models of the temporal and spatial distributions of currents and lake levels have been developed. Field and laboratory observations are being used for developing model parameters and for model verification.

191-08613-810-54

HYDROLOGIC TRANSPORT OF MATERIALS IN ECOSYSTEMS

(*b*) National Science Foundation.
(*c*) Dr. D. D. Huff.
(*d*) Theoretical and field investigation; basic and applied interdisciplinary research.

(*e*) To provide digital computer simulation of the hydrology of the Lake Wingra, Wisconsin drainage basin. Results include basin water balance, urban storm drain flow simulations, and soil water dynamics. The second goal is the coupling of nutrient movement to water flux.
(*h*) **Hydrologic Simulation and the Ecological System,** D. D. Huff, *3rd Intl. Seminar for Hydrology Professors*, Purdue University, Lafayette, Ind., July 1971, preprints available through correspondent.

191-08614-070-33

UNSTEADY FLOW OF GROUNDWATER

(*b*) Dept. of the Interior, Office of Water Resources Research; National Science Foundation.
(*c*) Dr. P. L. Monkmeyer.
(*d*) Theoretical and experimental; basic and applied research for Ph.D. theses and M.S. project.
(*e*) Investigation of the effects of the seepage face and delayed yield on the location of the water table and the flow in unconfined aquifers, and the possibility of using seismic methods for the field determination of hydraulic conductivity in saturated, partially saturated and air-dry sands.
(*g*) The seepage face was found to decay exponentially with time for instantaneous drawdown and to affect free surface locations significantly near the outflow face. A simple numerical method has been developed for predicting the quantity and duration of delayed drainage to a moving water table. Theoretical equations describing the propagation of sound waves through the fluid phases of partially saturated and air dry porous media show good comparison with experiments.
(*h*) **Seepage Face Effects in Unsteady Groundwater Flow,** W. A. Murray, *Ph.D. Thesis* and *Technical Report*, Univ. of Wis., 1970, 135 pp.
Unsteady Inertial Effects in Fluid Flow Through Porous Media, J. A. Spooner, *Ph.D. Thesis* and *Technical Report*, Univ. of Wis., 1971, 143 pp.
Seepage Face Effects in Unsteady Groundwater Flow, W. A. Murray, P. L. Monkmeyer, *Hydraulics Div. Specialty Conf., ASCE*, Iowa City, Iowa, Aug. 1971.
Delayed Yield and Unsaturated Flow Above a Falling Water Table, J. P. Grant, W. A. Murray, P. L. Monkmeyer, Univ. of Wis., Water Resources Center, Madison, partial technical completion report, 1972.
Unsteady Flow of Ground Water, P. L. Monkmeyer, J. A. Hoopes, W. A. Murray, J. A. Spooner, C. S. Tong, J. P. Grant, Univ. of Wis., Water Resources Center, Madison, final technical completion report, 1972.

191-08615-470-44

WAVES IN MARINAS AND HARBORS

(*b*) Dept. of Commerce, Sea Grant Program.
(*c*) Dr. P. L. Monkmeyer.
(*d*) Theoretical and experimental; basic and applied research for Ph.D. theses and M.S. projects.
(*e*) Develop a faster and less expensive method of designing marinas and small harbors than to construct and test a physical model. The proposed method relies on a hybrid computer and electrically conducting paper to model short and long waves in a harbor. The method includes consideration of variable depth effects and partial wave absorption at the harbor boundaries.

191-08616-860-33

WATER QUALITY IMPROVEMENT OF LAKES AND RESERVOIRS BY SELECTIVE WITHDRAWAL METHODS

(*b*) Dept. of the Interior, Office of Water Resources Research; Ford Foundation.
(*c*) Dr. P. L. Monkmeyer.
(*d*) Theoretical and experimental; basic and applied research for Ph.D. theses and M.S. projects.
(*e*) Develop criteria for the successful use of pumping and related methods of destratification of lakes and reservoirs. In particular a theoretical and experimental program has been initiated to study the characteristics of stratified flow near the bottom of a lake in the vicinity of the intake pipe, when withdrawal is being effected.

191-08617-870-60

MIXING ZONE FOR WASTE EFFLUENTS DISCHARGED INTO SURFACE WATERS

(*b*) Dept. of Natural Resources (State of Wisconsin); NASA.
(*c*) Dr. J. A. Hoopes and Dr. J. R. Villemonte.
(*d*) Theoretical, laboratory and field experiments; basic and applied research for M.S. and Ph.D. theses.
(*e*) Federal and State Water Quality Standards make provision for a mixing zone in which waste effluents discharged into surface water bodies are diluted to a concentration obtainable by a certain degree of mixing with the ambient water body. The shape and extent of this mixing zone are dependent upon the type and characteristics of the effluent, outfall and receiving water body. The basic goals of this continuing investigation are to develop explicit relationships for the extent and shape of the mixing zone, and to apply aerial remote sensing methods to the definition of the boundaries and concentrations of waste effluents in the mixing zone. Such relationship for the mixing zone may be used in the establishment of definite and rational water quality guidelines; in the development of sampling and regulation programs by government agencies; and in the design and location of outfalls by industries and municipalities. In order to accomplish these basic goals, an integrated program of mathematical and laboratory modeling and field testing is being carried out.
(*g*) Ground and aerial measurements of waste effluent concentration patterns in the mixing zone have been carried out at seven sites on four rivers throughout the State. From these tests extensive data have been accumulated for the patterns of effluent mixing at these sites. A laboratory model study of the Weston Power Plant site has also been completed. A generalized mathematical model, which describes the concentration and velocity patterns due to an effluent discharge into a surface water body, has been formulated. This model, which incorporates the effects of outfall shape, location and discharge and the effects of river boundaries and velocities, is currently being adopted for numerical solution at each of the field sites, using parameters obtained from the field studies.

UNIVERSITY OF WISCONSIN, Marine Studies Center, 1225 W. Dayton Street, Madison, Wis. 53706. R. A. Ragotzkie, Director.

192-07971-870-44

PHYSICAL ASPECTS OF THERMAL POLLUTION

(*b*) Sea Grant Program and NASA Remote Sensing Program.
(*c*) T. Green.
(*d*) Field, basic research.
(*e*) Measurements are being made of the fine structure of a thermal plume on Lake Michigan.
(*g*) Detailed thermal imagery of the plume surface temperature has been obtained, together with surface velocity data.

192-07972-810-33

RAIN MIXING

(*b*) Office of Water Resources Research.
(*c*) T. Green.
(*d*) Laboratory, basic research.
(*e*) The depth to which rain penetrates a natural water surface is measured as a function of drop size, drop temperature, and ambient water temperature.

192-07973-440-54

COASTAL CURRENTS IN LAKE SUPERIOR

(*b*) National Science Foundation; NASA Remote Sensing Project.
(*c*) T. Green.
(*d*) Field, basic research.
(*e*) Photogrammetric methods are used to determine the fine structure of the velocity of the Keweenaw current.
(*g*) The fine structure can be determined using photogrammetric techniques.

192-07974-440-88

DYNAMICS OF LAKE CURRENTS

(*b*) Argonne National Laboratory.
(*c*) John Bennett.
(*d*) Theoretical; Doctoral thesis.
(*e*) Develop numerical models for flow in the Great Lakes and use them to interpret observations.
(*h*) **A Theory of Large Amplitude Kelvin Waves,** J. R. Bennett, 1972 AGU Annual Meeting.

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UNIVERSITY OF WISCONSIN, Department of Mathematics, Madison, Wis. 53706. Professor Wolfgang R. Wasow, Department Chairman.

193-08400-420-61

WATER WAVES IN THERMALLY STRATIFIED LAKES AND LONG RIVERS

(*b*) Wisconsin Water Resources Center.
(*c*) Professor M. C. Shen, R. E. Meyer.
(*d*) Theoretical; basic research for Ph.D. thesis.
(*e*) Mathematical methods are developed for studying water waves near the shores of large lakes and in long rivers.
(*f*) Completed.
(*g*) The geometrical optics method is applied to the determination of resonance frequencies of water waves near the shore of a stratified lake, and an integral transform method is used to study the generation of waves over a sloping beach and their development in time. Limit solutions of similarity type are obtained to determine the decay law of two-dimensional steady motion far ahead of a horizontally moving body in a stratified viscous fluid. A multi-parameter method is developed to describe and predict nonlinear wave motion in rivers of realistic cross-section taking account of viscosity and surface tension, and the stability of a gaseous jet discharged in a rotating viscous fluid.
(*h*) **Asymptotic Nonlinear Wave Motion of a Viscous Fluid in an Inclined Channel of Arbitrary Cross-Section,** M. C. Shen, S. M. Shih, Univ. of Wis., *Water Resources Center Report*, 1970.
Resonances of Unbounded Water Bodies, R. E. Meyer, *Lectures in Applied Mathematics, Amer. Math. Soc.* **13,** pp. 189-227, 1971.
Studies in Double Asymptotics and Stratified Fluid Flow, D. D. Freund, *Ph.D. Thesis*, 1971.
Contributions to the Sloping Beach Problem, M. Gwaiz, *Ph.D. Thesis*, 1972.
Asymptotic Theory of Helical Waves on a Gaseous Jet in a Rotating Viscous Fluid, M. C. Shen, Univ. of Wis., *Water Resources Center Report*, 1972.

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UNIVERSITY OF WISCONSIN-MILWAUKEE, College of Applied Science and Engineering, Milwaukee, Wis. 53201. Dr. R. G. Griskey, Dean.

194-08404-120-54

TRANSITION AND TURBULENT FLOW OF DILATANT FLUIDS

(*b*) National Science Foundation.
(*d*) An experimental project in applied research which utilizes Masters level graduate students.
(*e*) The laser-Doppler technique is used to study entrance lengths, velocity profiles and transition from laminar to turbulent flow with dilatant (shear-thickening) fluids.

194-08405-120-00

EXTENSIONAL FLOWS

(*c*) Dr. R. T. Balmer, Director, Rheology Laboratory and Assoc. Professor of Energetics.
(*d*) A theoretical and experimental project in basic research on extensional flows. Masters level graduate students are utilized.
(*e*) A hyperbaric Fanno chamber is used to measure the extensional viscosity of Newtonian and dilute non-Newtonian polymer solutions.
(*g*) A correlation between fluid column height and extensional viscosity has been developed.

194-08406-480-00

SECONDARY FLOWS IN ATMOSPHERES

(*c*) Dr. R. T. Balmer, Assoc. Professor.
(*d*) An experimental project in basic fluid mechanics research utilizing Masters level graduate students.
(*e*) Atmospheric instabilities are modeled with rotating liquids in order to reproduce certain phenomena such as the banding of Jupiter.
(*g*) A successful model has been built and data is being processed.
(*h*) **The Hygrocyst: A New Continuum Phenomenon,** R. T. Balmer, *Nature* **227,** 600, 1970.

194-08407-390-00

MECHANOCHEMICAL POWER GENERATION

(*c*) Dr. R. T. Balmer, Assoc. Professor and Director, Bioenergetics Laboratory.
(*d*) An experimental project directed toward producing significant amounts of mechanical power through the utilization of mechanochemical processes. Masters level students used.
(*e*) Reconstituted collagen is made to contract and relax in a controlled cycle producing enough net work to make a useful engine. Such an engine can use salt as a fuel and has virtually no thermal pollution or exhaust pollution.
(*g*) Various contractile systems are being investigated to characterize the materials.

194-08408-390-00

ELECTRO-OSMOTIC CONSOLIDATION OF HARBOR DREDGING WASTES

(*c*) Dr. Gilbert L. Roderick.
(*d*) Experimental, applied research.
(*e*) Laboratory study of electro-osmotic consolidation and drainage of harbor dredging disposed of by landfill methods. An electrically induced downward water flow should substantially increase the drainage rate and also result in a larger effective consolidating stress, thus improving the density, shear resistance, and other engineering characteristics of the final product in addition to decreasing the time required for drainage. Results will be used to predict voltage and current requirements for a possible practical field application of the method.

194-08409-390-44

REDUCTION OF BREAKOUT FORCES AND TIMES BY ELECTRO-OSMOSIS

(*b*) Sea Grant Program.
(*c*) Dr. Gilbert L. Roderick.
(*d*) Experimental, applied research.
(*e*) Laboratory model study of the effect of electrically induced water flow on the forces and times required to remove objects from soft cohesive underwater sediments. An attempt to remove an object from the sediment causes a decrease in pore-water pressures below the object resulting in a "mud-suction" which resists movement. This resistance is dissipated as water moves to the low pressure region. Electro-osmosis increases the flow rate and so reduces the time and/or force required to break the object free of the sediment. If effective, the method may have application in salvage operations.
(*g*) Data is being collected. Present data is insufficient for analysis and correlation.

194-08410-120-00

NUMERICAL SOLUTIONS OF HEAT, MASS AND MOMENTUM TRANSFER BOUNDARY LAYER EQUATIONS FOR NEWTONIAN AND NON-NEWTONIAN FLUID FLOW IN THE ENTRANCE OF CIRCULAR TUBE ANNULI

(*c*) Dr. V. L. Shah, Assoc. Professor, Department of Energetics.
(*d*) Theoretical, basic and applied research.
(*e*) Obtain the numerical solutions of parabolic differential equations of mass diffusion, momentum and energy for Newtonian and Non-Newtonian fluid flow. The numerical procedure employed is of the "Finite Difference Matching Integration Type." The results will then be applied to the physical situation of blood flowing through a semipermeable capillary tube (or annulus) with an ultimate goal of optimizing the designs of blood oxygenation and hemodialysis units.
(*g*) The capability, feasibility and accuracy of the program GMX4 (Heat and Mass Transfer in Boundary Layers by Patankar and Spalding) has been confirmed by comparing the results obtained from the program to known solutions of classical problems.

194-08411-050-54

HIGH PRESSURE LIQUID JETS

(*b*) National Science Foundation.
(*c*) Dr. Kenneth F. Neusen.
(*d*) Primarily experimental; both basic and applied aspects to the research.
(*e*) Investigate liquid jets at pressures up to 200,000 psi and at velocities exceeding the sonic velocity of the liquid composing the jet. Cutting and eroding effects of jets on targets of various materials will also be investigated.
(*g*) No experimental results available to date. Facility has been designed. Procurement and construction are under way.

194-08412-440-54

NUMERICAL STUDIES ON THE CIRCULATIONS AND STORM SURGES IN LAKE ONTARIO

(*b*) National Science Foundation.
(*c*) Desiraju B. Rao, Dept. of Energetics and the Center for Great Lakes Studies.
(*d*) Theoretical, applied research.
(*e*) Development of numerical models to study the storm surge prediction problem and problems of water circulation in the framework of the hydrodynamical equations of a rotating, quasi-static system. Lake geometry and bathymetry are included in the models.
(*f*) Work is progressing on a two-layer steady state and a one-layer time dependent model.
(*h*) **Calculation of the Steady State Wind-Driven Circulations in Lake Ontario,** D. B. Rao, T. S. Murty, *Arch. Met. Geoph. Biokl.* **19,** Ser. A, 195-210, 1970.
Wind-Generated Circulations in Lakes Erie, Huron, Michigan and Superior, T. S. Murty, D. B. Rao, *Proc. 13th Conf. Great Lakes Res.*, 927-941, 1970.

WOODS HOLE OCEANOGRAPHIC INSTITUTION, Woods Hole, Mass. 02543. Dr. Paul M. Fye, Director.

195-07786-450-20

DYNAMIC PROCESSES IN THE DEEP SEA

(*b*) Office of Naval Research.
(*c*) Dr. N. P. Fofonoff.
(*d*) Theoretical and field investigations.
(*e*) Time series observations in the deep ocean and theoretical studies are used in the determination of the nature of dynamic processes in the sea.
(*g*) From results of recent long records from moored current meters, the dynamics of the ocean are characterized not only by steady ocean-wide flows, but also by slow variable motions with hundreds of kilometers. It appears that these important eddy-like or wave-line motions are quasi-geostrophic and make up the bulk of the horizontal kinetic energy of the interior of the ocean.
(*h*) **Current Measurements in the Western Atlantic,** N. P. Fofonoff, F. Webster, *Trans. Roy. Soc. London A.* **270,** 1206, 423-436, 1971.

195-08401-450-54

INVESTIGATION OF INTERACTIONS BETWEEN SHORT INTERNAL GRAVITY WAVES AND LARGER-SCALE MOTION IN THE OCEAN

(*b*) National Science Foundation.
(*c*) Dr. Klaus F. Hasselmann.
(*d*) Theoretical and field investigations.
(*e*) By applying the theory of weak wave-wave interactions and weak-wave-current interactions, many properties of mixing processes can be evaluated.
(*g*) The dynamics of larger-scale motions in the ocean are strongly affected by smaller-scale mixing processes. In analogy with similar mixing processes in the atmosphere, existing measurements of small-scale, high-frequency fluctuations indicates that these are associated with quasi-linear internal waves, rather than nonlinear turbulence in the usual sense.
(*h*) **Determination of Ocean Wave Spectra From Doppler Radio Return From the Sea Surface,** K. Hasselmann, *Nature* **229,** 16-17, 1971.
On the Mass and Momentum Transfer Between Short Gravity Waves and Larger-Scale Motions, K. Hasselmann, *J. Fluid Mech.* **50,** 189-206, 1971.
The Energy Balance of Wind Waves and the Remote Sensing Problem, K. Hasselmann, *Proc. Conf. Sea Surface Topography from Space*, Key Biscayne (in press).

195-08402-060-20

INTERNAL WAVE INTERACTIONS

(*b*) Office of Naval Research.
(*c*) Dr. William F. Simmons.
(*d*) Theoretical and field investigations.
(*e*) A spectrum on internal and other waves in the ocean is determined by processes of generation, dissipation, interaction with surroundings, and self-interaction, the latter deriving from nonlinearity inherent in fluid flow. The aim is to study the processes experimentally with primary emphasis on nonlinear interactions of internal waves and with a view toward understanding their role in influencing the spectra of internal waves in the ocean.
(*g*) Experiments have documented the efficiency of energy transfer due to nonlinearity in carefully selected wave triads of small amplitude. It has been established conclusively that nonlinearity plays the significant role in redistributing line-spectra energy in both the frequency and mode number domain.

(*h*) **The Excitation of Resonant Triads by Single Internal Waves**, S. Martin, W. Simmons, C. Wunsch (submitted to *J. Fluid Mechanics*).

195-08403-450-20

LABORATORY MODELS OF OCEANOGRAPHIC PROCESSES

(*b*) Office of Naval Research.
(*c*) Dr. John A. Whitehead.
(*d*) Theoretical and field investigations.
(*e*) The use of the geophysical fluid dynamics laboratory to achieve a clearer understanding of buoyancy-driven instabilities.
(*g*) The study of steady-state Rayleigh-Bnard convection, the study of finite-amplitude Rayleigh-Taylor instability, and the study of steady-state, double-diffusive flows share many common features. This is apparent when the governing stability equations are examined. These show that disturbances to a steady state acquire energy to grow from the work performed by buoyancy-driven motions.
(*h*) **Instabilities of Convection Rolls in a High Prandtl Number Fluid**, F. H. Busse, J. A. Whitehead, *J. Fluid Mech.* **47**, 305-320, 1971.
Cellular Convection, J. A. Whitehead, *American Scientist* **59**, 444, 1971.
Boundary Conditions Imposed by a Stratified Fluid, J. A. Whitehead, *Geophys. Fluid Dyn.* **2**, 289-298, 1971.
The Generation of Mean Flows by a Negative Reynolds Stress, *ASME No. HTD* **4**, 1971.
Observations of Rapid Mean Flows Produced in Mercury by a Moving Heater, J. A. Whitehead, *Geophys. Fluid Dyn.* (in press).

WORCESTER POLYTECHNIC INSTITUTE, Alden Research Laboratories, Worcester, Mass. 01609. Professor Lawrence C. Neale, Director, Research Laboratories.

196-01963-700-70

METER CALIBRATIONS

(*b*) Foxboro Company.
(*d*) Experimental, for design.
(*e*) Calibration of various sizes of magnetic flow tubes (1" to 36" diameter) and a variety of nozzle and orifice plate assemblies.
(*f*) Tests in progress.

196-03859-700-70

METER CALIBRATIONS

(*b*) B-I-F Industries, Providence, R. I.
(*d*) Experimental, for design.
(*e*) Calibration of open flow nozzles and flow tubes up to 48" in diameter. Tests performed in standard test loop and also in mock-up of particular field installations.
(*f*) Tests in progress.

196-04255-700-70

METER CALIBRATIONS

(*b*) Badger Meter Company, Milwaukee, Wis.
(*d*) Experimental; for design.
(*e*) Calibration of open flow nozzles and flow tubes from 2" to 48" in diameter in the standard test loop. In addition, tests have been performed to determine operating characteristics in a variety of field installation mock-ups including a number of pipe surface finishes.
(*f*) Tests in progress.

196-04746-700-70

METER CALIBRATIONS

(*b*) Hagan Chemicals and Controls, Inc., Pittsburgh, Pa.
(*d*) Experimental, for design.
(*e*) Calibration of a variety of sizes and designs of flow nozzles and flow nozzle assemblies.
(*f*) Tests in progress.

196-05279-700-70

METER CALIBRATIONS

(*b*) ITT General Controls, Warwick, R. I.
(*d*) Experimental, for design.
(*e*) Calibration of flow tubes in a range of sizes from 6" to 48" has been carried out. Field piping as well as standard test loop installation have been used.

196-05962-700-70

METER CALIBRATIONS

(*b*) Bailey Meter Company, Wickliffe, Ohio.
(*d*) Experimental, for design.
(*e*) Calibration of flow nozzles and flow meters in standard as well as particular metering and piping configurations for a range of sizes from 1" to 16" diameter.

196-05963-700-70

METER CALIBRATIONS

(*b*) Fischer and Porter Company.
(*d*) Experimental for design.
(*e*) Calibration of various sizes of magnetic flow tubes from 2" to 48" diameter.

196-06505-420-75

PILGRIM NUCLEAR POWER PLANT

(*b*) Bechtel Corporation, San Francisco, Calif.
(*d*) Experimental, for design.
(*e*) A 1/50 scale model of a section of Massachusetts Bay near the Boston Edison Company plant was constructed to evaluate storm protection at the proposed plant. A 4000 ft. section of the shore line and the bay for an equal distance offshore were reproduced including the plant cooling water inlet and outlet structures. A 40-ft. long variable speed and variable stroke wave maker was installed to generate the storm driven waves. Electronic probes were installed at critical locations to measure and record wave heights and frequencies. A variety of breakwater configurations and combinations are being tested as part of the program.
(*f*) Tests completed. Report in preparation.

196-06509-870-73

INDIAN POINT STEAM PLANT

(*b*) Consolidated Edison Company, New York.
(*d*) Experimental, for design.
(*e*) A 1/250 horizontal by 1/60 vertical scale model of a section of the Hudson River is being constructed for the Consolidated Edison Company. A 4.5 mile section of the river including the Indian Point development of units one, two and three will be studied. The model will be operated to reproduce automatically the tide cycle and will be used to study the flow patterns of the heated cooling water on return to the river. The measurements will include the flows, detailed velocities and temperature profiles over the river.
(*f*) Tests in progress.

196-06510-340-73

CORNWALL PUMPED STORAGE DEVELOPMENT

(*b*) Consolidated Edison Company.
(*d*) Experimental, for design.
(*e*) A 1/150 horizontal by 1/75 vertical scale model of a section of the Hudson River was modeled including the section at the tailrace of the plant. The studies involved determination of optimum shape of the tailrace and flow patterns and velocities for various phases of plant operation and various tide conditions. Protection of marine life in the river was also studied.
(*f*) Tests completed. Report on file.

196-06512-340-73

JOCASSEE PUMPED STORAGE DEVELOPMENT

(*b*) Duke Power Company.
(*d*) Experimental, for design.
(*e*) A 1/50 scale model of the upper reservoir was constructed for the Duke Power Company under the guidance of Charles T. Main, Inc., engineers. Included in the model was a section of the reservoir, the two intake structures, and sections of the tunnel beneath each structure. The study involved the interaction of the local topography and the flow into and out of the structures. Measurements of velocity for a variety of configurations were made both outside the structures in the reservoir and within the structures themselves. In addition a cylinder gate was constructed of fiberglass and instrumented with strain gauges to evaluate dynamic forces on the gate during various modes of operation.
(*f*) Tests completed. Report in file. Model held in readiness for additional tests.

196-06513-870-73

PEACH BOTTOM NUCLEAR STATION

(*b*) Philadelphia Electric Company.
(*d*) Experimental, for design.
(*e*) A 1/300 horizontal by 1/30 vertical scale model of the section of the Susquehanna River between Holtwood Dam and Conowingo Dam was constructed. In addition to the Holtwood and Conowingo installations the Muddy Run Pumped Storage Plant is included. At the Peach Bottom site a variety of intake and outlet structures will be studied in evaluating the heat effect on the reservoir of the Peach Bottom cooling water. Weekly cycles of plant operation at all four power stations are modeled during a test and temperature measurements at approximately 250 locations are recorded every minute of model operation. The reservoir temperature is varied from 40°F to 85°F and plant increase has been varied from 8°F to 30°F.
(*f*) Tests in progress.

196-06514-870-73

MORGANTOWN STEAM POWER STATION

(*b*) Potomac Electric Power Company.
(*d*) Experimental, for design.
(*e*) A 1/400 horizontal by 1/40 vertical scale model of a 16-mile section of the Potomac River has been constructed. This model includes the section of the Potomac between Upper Cedar Point and Swan Point and is in the tidal range of the river. The controls are designed to automatically produce the selected tide cycle in the model and to produce river temperatures from 40°F to 85°F. In addition the incremental temperature is applied to the plant flow and can be varied over a range from 0 to 30°F. The study is being conducted to evaluate the heat effect of the condenser cooling water in the river. Instrumentation has allowed approximately 150 temperature probe locations to record data each minute of operation.
(*f*) Tests completed. Report on file. Model held in readiness for additional tests.

196-06835-700-70

METER CALIBRATIONS

(*b*) Ramapo Instruments Company, Bloomingdale, N. J.
(*d*) Experimental, for design.
(*e*) Calibration of large type flow meters for application in pipes varying in size from 8" in diameter to 48" in diameter.

196-07792-340-75

GILBOA PUMPED STORAGE PROJECT

(*b*) Charles T. Main, Inc.
(*d*) Experimental, for design.
(*e*) A 1/75 scale model of the upper reservoir of the Gilboa Project of the Power Authority of the State of New York has been constructed. The study is designed to evaluate the performance of a number of different intake-outlet designs for the reservoir. These structures must insure a smooth flow without vortex formation and provide elimination of floating ice and other debris from the generating flow. Flow-away characteristics and possible scour were studied during the pumping phase.
(*f*) Tests completed. Report on file. Model held in readiness for further tests.

196-07793-340-75

GILBOA PUMPED STORAGE PROJECT

(*b*) Charles T. Main, Inc.
(*d*) Experimental, for design.
(*e*) A 1/50 scale model of a section of the lower reservoir has been constructed for the Power Authority of New York. This section includes the spillway stilling basin and several thousand feet of downstream river bed. The study has involved the approach flow to the spillway, the operation of the spillway and stilling basin. Also involved was the distribution of flow and velocity patterns in the river downstream. Finally the spillway radial gates will be calibrated in place.
(*f*) Tests completed. Report on file. Model held in readiness for further tests.

196-07795-340-75

BEAVER VALLEY NUCLEAR POWER STATION

(*b*) Stone and Webster Engineering Corp., Boston, Mass.
(*d*) Experimental, for design.
(*e*) A 1/125 horizontal by 1/25 vertical distorted scale model of a section of the Ohio River at the site of Shippingport and Beaver Valley Station sites of the Duquesne Light Company was constructed and tested. The present Shippingport plant intake and outlet were included in order to monitor any effect on the operating temperatures due to operation of Beaver Valley plant. Warm water properly scaled was used to model both plant flows. Data was obtained by continuous records at 150 locations in the model. Location and type of structure for both intake and outlet of Beaver Valley plant were studied.
(*f*) Tests completed. Report on file. Model held in readiness for further tests.

196-07796-340-75

LUDINGTON PUMPED STORAGE PROJECT

(*b*) Ebasco Services, Inc., New York City.
(*d*) Experimental, for design.
(*e*) A 1/122 scale model of the upper reservoir of the Ludington station of the Consumers Power Company and the Detroit Edison Company was constructed. The model included all the topography within the reservoir as well as the intake structure and a portion of each of the penstocks. The study involved an evaluation of flow patterns in the reservoir during both pumping and generating modes to insure adequate protection of structure and embankments. Also the possibility of unusual flow conditions at the intake was studied for a generating mode. During this same mode head loss measurements in the intake and penstock entrances have been measured.
(*f*) Tests completed. Report on file. Model held in readiness for further tests.

196-07798-870-75

JAMES A. FITZPATRICK NUCLEAR STATION

(*b*) Stone and Webster Engineering Corp., Boston, Mass.
(*d*) Experimental, for design.
(*e*) A 1/80.1 scale model of section of Lake Ontario adjacent to the Fitzpatrick plant site of the Power Authority of the State of New York was constructed and tested. The model included the intake and outlet for condenser cooling water as well as the influence of the outflow from nearby Nine Mile Point Power Station. The tests involved thermocouple

readings to survey the model area and evaluate structural or operating changes. Patterns of elevated temperature water were developed from this type of data.
(*f*) Tests completed. Report on file.

196-07799-630-70

CALVERT CLIFFS NUCLEAR POWER PLANT

(*b*) Foster Wheeler Corporation.
(*d*) Model pump performance.
(*e*) A 12-inch model of the main circulating water pumps for the Baltimore Gas and Electric Company's Calvert Cliffs Nuclear Power Plant is being assembled for test to determine its performance characteristics in the ARL 100-HP pump test rig.
(*f*) Test completed. Report on file.

196-07800-630-70

NEW MADRID STEAM PLANT

(*b*) Foster Wheeler Corporation.
(*d*) Model pump performance.
(*e*) A 12-inch diameter model of the 84-inch VA main circulating water pump for the New Madrid Steam Plant was tested to determine its performance characteristics in the ARL 100-HP vertical pump test rig. The test rig is designed for a flowrate of 10,000 gpm which is measured with a calibrated venturi. The 100-HP direct current motor is mounted on the rig as a driving dynamometer with a selected speed range of 650 to 1600 rpm. Models up to 14 inches in diameter may be tested in this rig. A smaller 40-HP test rig is also available for model tests.
(*f*) Tests completed. Report on file.

196-07801-630-70

EAGLE MOUNTAIN NO. 3

(*b*) Foster Wheeler Corporation.
(*d*) Model pump performance.
(*e*) A 12-inch diameter model of the main circulating water pump for the Texas Electric Service Company's Eagle Mountain No. 3 Station was tested to determine its performance characteristics in the ARL 100-HP pump test rig.
(*f*) Tests completed. Report on file.

196-07803-870-75

OYSTER CREEK NUCLEAR POWER STATION

(*b*) Burns and Roe, Inc.
(*d*) Experimental, for design.
(*e*) A 1/50 scale model of an area surrounding the cooling water outlet of the Oyster Creek Plant of the Jersey Central Power Company was constructed and tested. The basin containing the studies was approximately 30 feet by 40 feet in area. The outlet pipe was modeled and the data taking consisted of temperature and velocity surveys over the basin. Warm water at various temperatures was released through the outlet to simulate various operating conditions.
(*f*) Tests completed. Report on file.

196-08413-350-73

FIFE BROOK SPILLWAY STUDY

(*b*) New England Power Service Company.
(*d*) Experimental, for design.
(*e*) A 1 to 44.44 uniform scale model of the proposed Fife Brook Spillway, including a portion of the upstream reservoir and the river well downstream of the site was designed and constructed. Included in the model was the dam, powerhouse intake, spillway approach, spillway with gates, spillway chute, powerhouse tailrace and plunge pool. The main purpose of the study was to insure the safety of the structures and to minimize scour in the downstream area. The adequacy of the spillway chute and spillway gates was checked and a head capacity relationship over a range of gate openings was developed.
(*f*) Tests completed. Report on file. Model held in readiness for further tests.

196-08414-390-75

SALEM HARBOR DUCTWORK (UNIT 4)

(*b*) Charles T. Main Engineers, Inc.
(*d*) Experimental, for design.
(*e*) A 1/10 scale model was constructed of the duct work from the exit of forced draft fans to the inlet side of the rotary regenerative air preheater. The study was conducted to determine and improve the velocity distribution at the entrance to the air preheaters and to minimize the pressure drop in the duct work.
(*f*) Tests completed. Report in preparation.

196-08415-340-73

BRIDGEPORT INTAKE STUDY

(*b*) United Illuminating Company.
(*d*) Experimental, for design.
(*e*) A 1/16 scale model of one bay of the cooling water intake at the Harbour Steam Generating Station of the United Illuminating Company is under study. The study involves investigating the flow patterns through the racks and screens leading to the circulating water pump. At the present time the pump bell and casing are experiencing repeated structural failures while vibration and acceleration measurements are indicating a flow induced force field on the pump. Various modifications to the structure are being modeled to effect the most efficient improvement.
(*f*) Tests completed. Report on file.

196-08416-340-73

McGUIRE INTAKE STUDY

(*b*) Duke Power Company.
(*d*) Experimental, for design.
(*e*) A 1/15 scale model of the intake structure for cooling water at the McGuire Nuclear Power Station of the Duke Power Company on Lake Norman. The model includes a section of the reservoir upstream on the intake and a passive pump bell and barrel on the downstream side of the modeled structure. The design incorporates separate water supply as a manifold and discharge pipe set behind the curtain wall in each bay to supplement water taken directly from the reservoir. This supply is drawn from the deep portions of the reservoir at the upstream face of the nearby Cowans Ford dam. In addition to investigating flow patterns during normal operation it is intended to study the flow with various combinations of flow from the reservoir and manifold.
(*f*) Tests in progress.

196-08417-630-73

PUMP TEST PROGRAM

(*b*) Foster-Wheeler Company.
(*d*) Experimental, for design.
(*e*) In cooperation with the Foster-Wheeler Company, several pump models are being evaluated as a part of a development and background research project. This program is being carried out on the 100-HP variable speed test rig. The work is being conducted in close cooperation with the sponsor so as to have the program reflect the latest data and up-to-date designs from Foster-Wheeler. The details of the 100-HP test rig and the associated equipment are available in the Alden Research Laboratories' Brochure on Fluid Machinery Testing.
(*f*) Test completed. Report on file. Model held in readiness for further tests.

196-08418-340-75

BRUNSWICK SYPHON MODEL STUDY

(*b*) United Engineers and Constructors, Inc.
(*d*) Experimental, for design.

(e) A 1/26 scale model of the inverted syphons in the cooling water discharge system of the Brunswick Plant of the Carolina Power and Light Company was constructed and tested. The tests include an evaluation of the overall performance of the syphons plus a detailed investigation of entrance, exit and bend losses in order to optimize the operation. In addition to the syphons the canal transitions and adjacent topography were included in the model and in the investigations.
(f) Test completed. Report on file. Model held in readiness for further tests.

196-08419-440-75

QUABBIN RESERVOIR MODEL

(b) New England Research Inc.
(d) Experimental, for design.
(e) A 1/4000 × 1/200 scale model of the Quabbin Water Supply Reservoir of the Massachusetts Metropolitan Commission was constructed and tested in cooperation with the New England Research Company. The model was designed to include the various dikes and dams which created the reservoir as well as the various intakes, outlets and river sources for the reservoir. The study has been aimed at documenting the density currents and transit characteristic of inputs at various locations in the upper reservoir. Dyes and other tracers have been used along with a variety of photographic techniques to obtain the required data.
(f) Tests completed. Report on file. Model held in readiness for further tests.

196-08420-870-73

LAKE NORMAN MODEL STUDY

(b) Duke Power Company.
(d) Experimental, for design.
(e) Lake Norman, on the Catawba River in North Carolina, was formed by construction of the Cowans Ford Dam completed in 1963. Lake Norman is a reservoir of approximately 32,500 acres with a volume of approximately 1,000,000 acre feet. Cowans Ford was built as a multipurpose project, including hydro power generation, water supply, flood control, recreation and to serve as a source of condenser cooling for thermal power generating stations. There are a number of thermal station sites on the lake, one of which is Marshall Steam Station, a fossil fuel plant, completed in 1970, having a capacity of 2137 megawatts with four units. The William B. McGuire Nuclear Station under construction, is located near the Cowans Ford Dam. McGuire has two units of 1150 megawatts each for a total of 2300 megawatts. Two other sites will probably be developed in the 1980's. The model of Lake Norman is located in a building 182 feet long by 90 feet wide and is constructed to a scale ratio of 1:600 horizontally and 1:60 vertically. The corresponding velocity ratio is 1:7.75 and the flow ratio is 1:278,855. The condenser cooling water temperature rise is simulated by heating water with electric element heaters. A Model 300 Data-logger acquisition system scans and records 300 individual temperature sensing thermistor points in the model. Heat patterns on the surface and in depth are then obtained in the lake.
(f) Tests in progress.

196-08421-340-73

PARR HYDRO-ELECTRIC PROJECT

(b) South Carolina Electric and Gas Company.
(d) Experimental, for design.
(e) The Broad River is dammed at Parr Shoals to form Parr Reservoir and a fossil fuel steam plant of 70,000 kW and a hydro-electirc plant of 14,880 kW are located at or near the dam. Under the proposed project the dam would be elevated to increase the capacity of the Parr Reservoir which would also serve as the lower reservoir for the pumped-storage scheme. The upper reservoir will be formed by damming Frees Creek with a main dam 5000 feet in length and two extensive saddle dams each approximately 3000 feet in length. The total impoundment would contain approximately 400,000 acre-feet (1.3 billion gallons) of water. The elevation difference between the upper reservoir and the lower reservoir would be 157 feet with both reservoirs filled to capacity. The proposed pumped-storage plant utilizing this head would have a total installed capacity of 480 MW. The upper reservoir is being studied as a possible site for a nuclear plant of at least two units. Studies are currently in progress to determine the size and location of these units. The model of the two reservoirs and associated power plants is situated in a building 140 feet long by 50 feet wide and is constructed to a scale of 1 to 50 vertical and 1 to 500 horizontal. Broad River flows, steam and nuclear condenser flows and pumped storage flows are properly modeled using calibrated metering sections in each of the respective plants. In the case of the fossil fuel and the nuclear plant the temperature rise across the condensers is also modeled. Heat patterns at the surface and in depth are obtained on both the upper and lower reservoir by use of thermocouples or thermistors along with suitable instrumentation.
(f) Tests in progress.

196-08422-870-73

ZION DISCHARGE MODEL STUDY

(b) Commonwealth Edison Company.
(d) Experimental, for design.
(e) A 1/25 scale model of one outlet structure was installed in a basin in order to study the near field temperature and flow patterns resulting from the operation of the unit. The basin was arranged to allow a range of lake currents to be imposed on the model. Also the temperature of the outlet water could be adjusted to provide a range of differential temperatures between the basin water and the outlet. The outlet was constructed of clear plastic to give a view of the flow patterns inside the structure. Evaluation of the effectiveness of a number of structural changes was made during the course of the study.
(f) Tests completed. Report on file.

196-08423-340-75

ASTORIA PLANT-UNIT 6 INTAKE STUDY

(b) Ebasco Services, Inc.
(d) Experimental, for design.
(e) A 1/10.7 scale model of a portion of the East River including the intake for Unit 6 cooling water system of Consolidated Edison-Astoria Plant was constructed. The model of the 4-bay structure was set up with a mock-up of details such as screens and racks and the pump bellmouth laid up in fiberglass to the correct shape. The piping from the pump was arranged as a syphon to permit a passive test. The model study provided flow patterns and flow velocities to be determined at various critical sections for a variety of intake configurations, plant operating conditions and river flows.
(f) Tests completed. Report on file. Model held in readiness for further tests.

196-08424-870-73

YORKTOWN STEAM POWER STATION

(b) Virginia Electric Power Company.
(d) Experimental, for design.
(e) A distorted model (1/60 and 1/465) of the tidal portion of the York River including a section of Chesapeake Bay at the mouth has been constructed for the Virginia Electric Power Company. The existing two units have been modeled and tested with the present intake canal and shoreline surface discharge for the condenser cooling water. The tidal flow and stage are produced automatically at the bay end of the model. Temperature data is taken with thermocouple sensors with a data logger on punched

tape. After confirming the model data with the existing units by means of data from the field the third unit with a different outlet design (jet discharge–offshore) was installed and tested. In addition a new design of outlet for Units 1 and 2 (similar to Unit 3) was tested. The requirement by the regulatory agency requires a temperature rise no greater than 1.5 degrees F extending fully across the estuary.

(*f*) Tests completed. Report on file.

196-08425-350-75

TARBELA DAM PROJECT

(*b*) Tippets, Abbett, McCarthy and Stratton.
(*d*) Experimental, for design.
(*e*) A 1/80 scale model of both the Tarbela Spillways (Service and Auxiliary) is being tested for TAMS who are the designers for the Water and Power Authority of Pakistan. The model includes sections of reservoir upstream of each spillway, the discharge chutes and aprons and approximately one-half mile of the Dal Darra or channel downstream. The purpose of the study is to investigate the scour of the poor rock downstream of the spillways and to review experimentally any modifications necessary to insure the safety of the spillways. The data has been developed using miniature current meters and Pitot tubes for the velocities while plan view photographs have been the main source of scour data.
(*f*) Tests completed. Report in progress.

196-08426-700-70

WESTINGHOUSE L.E. SONIC FLOW METER

(*b*) Westinghouse Electric Corporation.
(*d*) Experimental, for design.
(*e*) A 20" diameter ultrasonic flow meter was calibrated in the 100,000 pound weigh tank loop. The upstream flow distribution was varied and measured in order to evaluate its effect on performance.
(*f*) Tests completed. Report on file.

196-08427-870-75

ROSETON STEAM POWER STATION

(*b*) Quirk, Lawler and Matusky.
(*d*) Experimental, for design.
(*e*) A 1/90 scale model of a two-mile section of the Hudson River including the existing Danskammer Plant and the proposed Roseton Plant of the Central Hudson Power Company has been constructed in cooperation with Quirk, Lawler and Matusky. The model is designed to reproduce the tidal effects at this section automatically and to reproduce the flows and temperature rises of both plants. The study is to determine the patterns of increased temperature in the Hudson River for a range of operating conditions on each plant and with a variety of intake and outlet structures. The model is being instrumented with thermocouples to give the required temperature sensing coverage.
(*f*) Tests in progress.

196-08428-870-75

BEAVER VALLEY NUCLEAR POWER PLANT

(*b*) Stone and Webster Engineering Corporation.
(*d*) Experimental, for design.
(*e*) A 1/125-1/25 model of two mile stretch of the Ohio River was constructed and tested to document the flow patterns of the warm water effluent of the Beaver Valley and Shippingport Nuclear Stations of the Duquesne Electric Company. The instrumentation included provision for modeling the cooling water systems including temperature and 150 remote temperature sensors and associated recording equipment to monitor model performance. Testing program was completed over one year ago but recent major modifications to river topography and further planned changes have necessitated reactivating the model during the fall of 1971 to document the effects of these changes on the temperature patterns in the river.
(*f*) Tests completed. Report on file. Model held in readiness for further tests.

196-08429-340-75

DAVIS PUMPED STORAGE DEVELOPMENT

(*b*) Ebasco Services, Inc.
(*d*) Experimental, for design.
(*e*) A 1/50 scale model of a section of the Upper Reservoir including the intake/outlet is being constructed for Ebasco Services, Inc., who are the designers acting for the Allegheny Power Service Corporation. The model is approximately 60 feet × 80 feet in plan and includes approximately 50 percent of the upper reservoir. The studies are being carried out to optimize flow entering or leaving the structure and to eliminate undesirable effects such as vortex formation non-uniform flow. The model is about 50 percent completed and should be completed within the month and testing will then proceed for a period of several months. The construction is a fiberglass shell representing the topography and the entire model is constructed over an existing model which is being preserved.
(*f*) Tests in progress.

PROJECT REPORTS FROM U.S. GOVERNMENT LABORATORIES

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division

CORN BELT BRANCH, 108 Soil Science Building, University of Minnesota, St. Paul, Minn. 55101. Dr. C. A. Van Doren, Branch Chief.

300-0185W-810-00

PREDICTING RUNOFF AND STREAMFLOW FROM LOESS AND CLAYPAN WATERSHEDS IN MISSOURI AND IOWA

See Water Resources Research Catalog **6**, 2.0951.

300-0186W-220-00

RATES AND PROCESSES OF RESERVOIR SEDIMENTATION IN THE CORN BELT

See Water Resources Research Catalog **6**, 2.0952.

300-0187W-810-00

SOIL AND VEGETATION INFLUENCES UPON HYDROLOGY OF THE CENTRAL CLAYPAN AREAS

See Water Resources Research Catalog **6**, 2.0953.

300-0188W-810-00

SEDIMENT YIELDS FROM AGRICULTURAL WATERSHEDS IN THE CORN BELT

See Water Resources Research Catalog **6**, 2.0954.

300-0189W-810-00

MANAGEMENT PRACTICES FOR CONTROL OF RUNOFF, EROSION, AND TILTH–CLAYPAN SOILS

See Water Resources Research Catalog **6**, 4.0176.

300-0190W-810-00

EFFECTS UPON STREAM FLOW OF TERRACING DEEP LOESS SOILS

See Water Resources Research Catalog **6**, 4.0177.

300-0191W-830-00

EROSION PROCESS IN LOESS GULLIES AND CONSOLIDATION OF GULLIES

See Water Resources Research Catalog **6**, 4.0235.

300-0192W-810-00

THE MOVEMENT AND YIELD OF NUTRIENTS FROM AGRICULTURAL WATERSHEDS

See Water Resources Research Catalog **6**, 5.0788.

300-0193W-840-00

NEW MATERIALS, EQUIPMENT AND TECHNIQUES FOR DRAINAGE OF AGRICULTURAL LANDS

See Water Resources Research Catalog **6**, 4.0213.

300-0194W-840-00

DRAINAGE REQUIREMENTS OF AGRICULTURAL LANDS AS RELATED TO FARMING OPERATIONS

See Water Resources Research Catalog **6**, 4.0214.

300-01723-350-00

HYDRAULICS OF WATER CONTROL STRUCTURES AND CHANNELS

See St. Anthony Falls Hydraulic Lab. Project Nos. 00111, 01168, and 07677. See also Illinois State Water Survey Division, Project No. 01865.

(*b*) Cooperative with the Minnesota Agric. Expmt. Sta.; the St. Anthony Falls Hydraulic Lab.; and the Illinois State Water Survey.
(*c*) Mr. Fred W. Blaisdell, Research Investigations Leader, St. Anthony Falls Hydraulic Lab., 3rd Ave. S.E. at Mississippi River, Minneapolis, Minn. 55414.
(*d*) Experimental; applied research for development and design.
(*e*) Research dealing with the design, construction, and testing of structures for conserving and controlling soil and water are carried out. Cooperation with and coordination of the tests at the Stillwater, Oklahoma, Outdoor Hydraulic Laboratory and the Illinois State Water Survey are maintained. A square drop inlet having a hood barrel entrance is being tested to determine entrance loss coefficients for various drop inlet sizes and heights and various barrel slopes. Previous tests have evaluated the performance of this type of inlet. The elbow and transition between the two-way drop inlet and the barrel is being studied to determine the pressures and the best form to minimize the possibility of cavitation. The transition between a circular pipe and a rectangular cantilevered outlet has been studied to determine the best form of the transition. Studies are also being conducted on cantilevered outlets.
(*g*) Reports in preparation.
(*h*) **Energy Loss at Pipe Junctions,** F. W. Blaisdell, P. W. Manson, *Trans. ASCE* **135**, 833-835, 1970.

300-04275-830-00

MECHANICS AND CONTROL OF EROSION BY WATER

(*b*) Cooperative with Purdue University Agricultural Expmt. Station.
(*c*) W. H. Wischmeier and L. D. Meyer, Agric. Engrg. Bldg., Purdue U., Lafayette, Ind. 47907.
(*d*) Experimental, theoretical, and field investigations; basic, applied and developmental research.
(*e*) Field, laboratory, and analytical studies of soil detachment and transport by rainfall and runoff; effects of plant covers, crop residues, tillage methods, and soil treatments on erosion and runoff; hydraulics of eroding runoff and rainfall; and mathematical models of the soil erosion process as a basis for improved methods of erosion prediction and erosion control.
(*g*) Erosion along non-uniform land profiles was analyzed by applying a new equation derived from basic principles of sediment transport, hydraulics and erosion mechanics. Closed-form solutions were obtained for several slope shapes. The new basic model separates the erosion process into several subprocesses. This procedure helped to ac-

count for variations in effects of slope length, percent slope, and residue mulches. Separation of runoff-induced erosion from rainfall-induced erosion in closely coordinated field and laboratory studies supported the analytical findings. A relationship based on the soil-erodibility factor of the universal soil loss equation was found that satisfactorily predicted the coefficient of friction for simulation of runoff hydrographs and prediction of steady-state erosion rates on fallowed field plots. A nomograph was developed which graphically computes the empirical soil-erodibility factor of the erosion equation from the soil's physical properties. For erosion control on denuded 20 percent construction slopes, mulches of crushed stone or woodchips were found more effective than straw, and revegetation was quite successful where effective rates of these mulches had been used.

(*h*) **Soil Erosion by Water on Upland Areas,** L. D. Meyer, *River Mechanics* **II,** Chap. 27, H. W. Shen, Ed., 1971.

A Closed-Form Soil Erosion Equation for Upland Areas, G. R. Foster, L. D. Meyer, *Sedimentation (Einstein)*, Chap. 12, H. W. Shen, Ed., 1972.

A Soil-Erodibility Nomograph for Farmland and Construction Sites, W. H. Wischmeier, C. B. Johnson, B. V. Cross, *J. Soil and Water Conserv.* **26,** 5, 189-193, 1971.

Turbulence Characteristics of Overland Flow–The Effects of Rainfall and Boundary Roughness, I. T. Kisisel, A. R. Rao, J. W. Delleur, L. D. Meyer, *Water Resources and Hydromech. Lab. Tech. Rept. 28*, Purdue Univ., 145 pp., 1971.

Erosion, Runoff, and Revegetation of Denuded Construction Sites, L. D. Meyer, W. H. Wischmeier, W. H. Daniel, *Trans. ASAE* **1,** 138-141, 1971.

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division

NORTHEAST BRANCH, Plant Industry Station, Beltsville, Md. 20705. Dr. H. L. Barrows, Branch Chief.

301-04283-300-00

PROCESSES OF STREAM CHANNEL DEVELOPMENT IN THE NORTHEAST

(*c*) Paul H. Blinco, Hydraulic Engineer, ARS-USDA, Engineering Research Center, Colorado State University, Fort Collins, Colo. 80521.

(*d*) Experimental and field investigations.

(*e*) Determine turbulence characteristics in free-surface tilting flume and relate to boundary roughness; measure time average sediment concentration, local and mean boundary shear stress and relate to shear strength and density and structure of cohesive soil material; and establish regime behavior of natural channels as influenced by hydraulic flow, changes in flow patterns, sediment and channel alluvium characteristics.

(*f*) Discontinued.

301-04819-840-00

IMPROVED DRAINAGE SYSTEMS FOR AGRICULTURAL LANDS

(*b*) Cooperative with the Vermont Agricultural Experiment Station and the Soil Conservation Service.

(*c*) Mr. Joseph Bornstein, Agricultural Engr., Univ. of Vermont, Burlington, Vt. 05401.

(*d*) Field investigation both basic and applied research.

(*e*) Develop and evaluate drainage practices for sloping hardpan lands of the Northeast. This involves development of techniques for determining directional components of subsurface water flow before and after installation of drainage treatments. Surface and subsurface drainage practices are instrumented to measure runoff from rainfall and snowmelt. Measure has been made of the seasonal changes in soil moisture in relation to drainage treatment; evaluation of crop root development above and in fragipan layer, characterization of moisture-tension relationships of disturbed and undisturbed fragipan samples, including through the freeze-thaw cycle. Instrumentation of this project is completed and six years data are available on diversion ditch runoff and tile outflow. Extensive piezometric and soil moisture change and crop data are also available. Crop results include yield changes in botanical analysis, winterkill and alfalfa crown rot vs. drainage and plant heights. A seepage pit has yielded groundwater flow data by horizons.

(*f*) Suspended.

(*g*) Reports in preparation.

301-04820-810-00

HYDRODYNAMICS OF CHANNEL SYSTEMS IN AGRICULTURAL WATERSHEDS

(*b*) Cooperative efforts on occasion.

(*c*) Mr. H. N. Holtan, Director, USDA Hydrograph Lab., ARS-SWC, Beltsville, Md. 20705.

(*d*) Basic and applied research.

(*e*) Specific objectives of this project are to translate the complete system of hydrodynamics, i.e., the equation of continuity, the equation of state, and the equation of motion of fluids to a system appropriate to steady or unsteady flow (with lateral inflow and outflow) on land surfaces and through open channels; to define appropriate watershed and channel initial values and boundary conditions such as, surface or channel roughness, vegetation, materials and geometry, to insure meaningful watershed solutions to the hydrodynamical equations; to develop feasible numerical methods for solving hydrodynamic equations on analog or digital computers; and to work with other members of the USDA Hydrograph Lab. to verify the surface dynamic aspects of a methematical model of watershed performance.

(*g*) A general relation was developed for theoretically segmenting a hillslope into a number of cascades based on the sharpness of the curvature of the hillslope to hold errors of routing overland flow to an acceptable minimum within 10 percent. This is a useful criterion for evaluating the error induced by averaging the geometry and physical parameters in the mathematical modeling of watershed hydrology. Depending on the geometry and roughness of the watershed, it can easily be determined if the lagging by the overland flow computations is significantly relative to streamflow computations and vice versa. If either is true, that computational system can be deleted without any significant loss in accuracy. This finding can be used as an example for developing more general relations which would be useful in easing the computational load in a watershed hydrology model. Length, roughness, slope, and rainfall intensity determine the shape of the rising hydrograph of runoff from plane surfaces. The kinematic wave equations reproduced this effect accurately, while other mathematical models could not. A general computational model was developed which can generate realistic overland flow hydrographs for hillslopes, V-shaped watersheds with wide stream channels, and for various curved surfaces, and for more complicated watershed geometries. A flood routing technique, shorter and quicker to use than the cumbersome convolution of unit hydrographs, was developed from streamflow data at four tandem gaging stations on Mahantango Creek, Pa. Also, it was found that the dynamic terms in the momentum equation are negligible, that kinematic waves prevail over dynamic waves and therefore the result is nearly a pure translational effect. In addition to their practical applications in flood, these findings provide insight into events occurring in a watershed drainage system during a storm.

(*h*) **Estimation of Surface Water Lag Time From the Kinematic Wave Equations,** D. E. Overton, *Water Resources Bull., J. Amer. Water Resour. Assoc.* **7,** 3, 428-440, June 1971.

301-08432-810-00

PREDICTING RUNOFF AND STREAMFLOW FROM AGRICULTURAL WATERSHEDS IN THE NORTHEAST

(*b*) Cooperative with the Vermont Agric. Expmt. Sta., New Hampshire Agric. Expmt. Sta., and NOAA.
(*c*) Ronald Z. Whipkey, Research Investigations Leader, 150 Kennedy Drive, South Burlington, Vt. 05401.
(*d*) Experimental and field observations–applied and operational research.
(*e*) Hydrologically characterize important physiographic areas of the northeast, to study the effects of land use in local watershed hydrology and on downstream water supply and water quality. Specific research includes runoff processes (surface and subsurface) kinematics of overland flow, water input to watersheds from spring melt of northern snowpack, and hydrologic characteristics of watersheds as they affect water storage, transmission, drainage, and water availability for crop growth.
(*g*) A runoff model developed for Pennsylvania uplands aids in determining maximum areas of the watershed that contribute storm runoff as well as changes of contributing area depending on time and storm characteristics. Shallow water equations were tested on a major watershed stream and kinematic and dynamic wave motions studied; physical factors of importance in flood routing through natural channels were determined from this. Water input to watersheds arising from snowmelt is greatly affected by slope-aspect-cover and elevation in the physiographical complex watersheds of northern New England.
(*h*) **Scale Problems in Interdisciplinary Water Resources Investigation,** E. T. Engman, W. J. Gburek, L. H. Parmele, J. B. Urban, *Water Resources Bull.* **7,** 3, 495-505, June 1971.
Space Variations of Precipitation and Implications for Raingage Network Design, R. L. Hendrik, G. H. Comer, *J. Hydrology* **X,** 2, Feb. 1970.
Freezing and Thawing Effects on Drainage, G. R. Benoit, J. Bornstein, *Soil Sci. Soc. Amer. Proc.* **34,** 551-557, 1970.
Estimating Suspended Sediment Concentrations in Streams by Turbidity Measurements, S. H. Kunkle, *J. Soil and Water Conserv.* **26,** 1, 18-20, Jan.-Feb. 1971.
Application of Environmental Analysis to Watershed Snowmelt, R. L. Hendrik, B. D. Filgate, W. P. Adams, *J. Appl. Meteorology* **10,** 3, 418-429, June 1971.

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division

NORTHERN PLAINS BRANCH, P.O. Box E, Fort Collins, Colo. 80521. Dr. C. E. Evans, Branch Chief.

302-04826-840-00

FLOW IN POROUS MEDIA IN RELATION TO DRAINAGE DESIGN AND DISPOSAL OF POLLUTANTS

(*c*) Mr. Harold R. Duke, Agric. Engr., ARS, Engrg. Research Center, Colorado State Univ., Foothills Campus, Ft. Collins, Colo. 80521.
(*d*) Theoretical and experimental; applied research.
(*e*) A highly instrumented sand tank model of a parallel drain system is being used to determine the potential distribution and contribution of the partially saturated zone to the drain performance. The purpose is to provide an accurate means of drain design in fine-textured soil.
(*g*) A comprehensive theory has been developed to describe the physical processes of desaturation in porous media. This theory describes three distinct processes contributing to desaturation, and gives a mathematical description of each process. Two-dimensional similitude criteria have been verified for partially saturated flow systems. An analysis has been conducted to evaluate the effects of flow in the capillary region and of soil aeration requirements upon the design spacing of subsurface drains.
(*h*) **Capillary Properties of Soils–Influence Upon Specific Yield,** H. R. Duke, *Trans. ASAE,* (in press).
Boundary Effects in Desaturation of Porous Media, N. F. White, D. K. Sunada, H. R. Duke, A. T. Corey, *Soil Science* **113,** 1, pp. 7-13, Jan. 1972.
Models for Subsurface Drainage, W. E. Hedstrom, A. T. Corey, H. R. Duke, *Colorado State Univ. Hydrology Paper 48*, Apr. 1971.
Models for Subsurface Drainage, W. E. Hedstrom, *Ph.D. Thesis*, Colorado State Univ., Ft. Collins, Aug. 1970.
Physics of Desaturation in Porous Materials, N. E. White, H. R. Duke, D. K. Sunada, A. T. Corey, *I&D Div., ASCE* **96,** IR2, pp. 165-191, June 1970.

302-05567-840-00

AUTOMATION OF WATER DISTRIBUTION SYSTEMS FOR SURFACE IRRIGATION

(*c*) Dr. Howard R. Haise, Supervisory Soil Scientist, USDA, ARS, SWC, P.O. Box E, Fort Collins, Colo. 80521.
(*d*) Laboratory and field project; applied research.
(*e*) Develop labor-saving devices for surface application of irrigation water to farmfields for more efficient use of existing water supplies. Hydraulics of flow in border strips and furrows as affected by stream site, slope crop retardance, soil roughness and intake rate is evaluated as it relates to type of automation.
(*g*) Automation systems have been developed utilizing both pneumatic and hydraulic components to open and close irrigation gates in the field. Both types of system are operated from a central control point where predetermined water release times can be programmed. Turnout gates in lined, open ditches that can be operated by low-cost plastic hydraulic cylinders have been installed and operated at three field locations. Associated check structures are controlled automatically in proper sequence with the gates. At another location a field planted to row crops has been automated using hydraulically controlled pipe gates (designed specifically for this use) and an automatic water reuse system. Construction of large (10" by 10" throat) fluidic diverters of thin shell concrete for use in controlling streams of irrigation water has been proven feasible in the laboratory. A numerical solution solving the hydrodynamic equations for calculating the rate of advance and water surface profiles has been successfully programmed for the computer. Simulations have been made for borders up to 800 feet in length.
(*h*) **Automatic Cutback Furrow Irrigation System Design,** I. Nicolaescu, E. G. Kruse, *Irrig. and Drain. Div. J., ASCE Proc.* **97,** IR3, 343-353, 1971.
The Gates-Type Greenhouse Irrigation System: Design and Problems, H. R. Duke, J. J. Hanan, *Colorado Flower Growers Assoc. Bull. 245*, pp. 1-4, 1970.
Auto-Mechanization of Pipe Distribution Systems, H. R. Haise, P. E. Fischbach, *Natl. Irrig. Sym. Papers*, pp. M-1–M-15, 1970.
Automated Pipe-Valves for Surface Irrigation, H. R. Haise, E. G. Kruse, M. L. Payne, L. J. Erie, *Paper No. 70-745, Winter Mtg. ASAE,* Chicago, Ill., 16 pp., 1970.
Auto-Mechanization of Open Channel Distribution Systems, A. S. Humpherys, J. E. Garton, E. G. Kruse, *Natl. Irrig. Sym. Papers*, pp. L-1–L-20, 1970.
Automation of Surface Irrigation with Fluidic Diverters, E. G. Kruse, P. A. Freeman, H. R. Haise, *Trans. ASAE* **13,** 3, 357-361, 1970.
Automating Surface Irrigation: Controlling Butterfly Gates Hydraulically in Farm Lateral Turnouts, H. R. Haise, E. G. Kruse, L. Erie, *J. ASAE* **50,** 4, 212-216, 1969.
Automation of Surface Irrigation Systems: The State of the Art, H. R. Haise, E. G. Kruse, *J. Irrig. and Drain. Div., ASCE* **95,** IR4, 503-516, 1969.
Intake Function and Border Irrigation, J. R. Gilley, *M.S. Thesis*, Dept. of Agric. Engr., Colo. State Univ., Ft. Collins, 1968.
Low Gradient Border Irrigation, M. Payne, *M.S. Thesis*, Dept. of Agric. Engr., Colo. State Univ., Ft. Collins, 1969.

517-020 O-LT - 74 - 11

302-07001-810-00

SIMULATION OF HYDROLOGIC SYSTEMS

For summary, see Colorado State University, Engineering Research Center.

302-08433-220-00

SEDIMENT DETACHMENT, TRANSPORT AND DEPOSITION PROCESSES

(*b*) Laboratory project in cooperation with Colorado State University.
(*c*) Paul H. Blinco, Hydraulic Engineer, ARS-USDA, Engrg. Res. Center, Colorado State University, Ft. Collins, Colo. 80521.
(*d*) Theoretical and experimental; basic and applied.
(*e*) Determine the probability distribution of the instantaneous boundary shear stress and Reynolds stress near a smooth wall for varying open channel flows and to develop a stochastic model of the sediment detachment and entrainment processes based on turbulent structure in open channel flow.
(*g*) The flume has been instrumented and experimental investigations are about to begin.

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division

NORTHWEST BRANCH, P.O. Box 1187, Boise, Idaho 83701. Mr. J. C. Stephens, Branch Chief.

303-0195W-810-00

INFLUENCE OF CLIMATIC, BIOLOGIC, AND PHYSICAL FACTORS ON RANGELAND WATERSHED HYDROLOGY

See Water Resources Research Catalog **6,** 2.0581.

303-0196W-810-00

REYNOLDS CREEK EXPERIMENTAL WATERSHED STUDY

See Water Resources Research Catalog **6,** 2.0582.

303-0197W-300-00

EFFECT OF CHANNEL CHARACTERISTICS ON FLOW RESISTANCE AND ROUTING OF STREAMFLOW

See Water Resources Research Catalog **6,** 2.0583.

303-0198W-810-00

PRECIPITATION PATTERNS ON UPSTREAM WATERSHEDS IN THE NORTHWEST

See Water Resources Research Catalog **6,** 2.0585.

303-0199W-820-00

GROUNDWATER IN RELATION TO MANAGEMENT OF RANGELAND WATERSHEDS IN THE NORTHWEST

See Water Resources Research Catalog **6,** 2.0586.

303-0200W-840-00

EFFECT OF IRRIGATION UPON FLOW REGIME OF HEADWATER STREAMS IN THE NORTHWEST

See Water Resources Research Catalog **6,** 4.0119.

303-0201W-810-00

EFFECT OF RUNOFF, PRECIPITATION, CLIMATE, SOIL, VEGETATION, LAND USE, AND LANDFORM ON SEDIMENT YIELD

See Water Resources Research Catalog **6,** 4.0120.

303-0202W-810-00

CLIMATE, SOIL, AND VEGETATION INFLUENCES ON HYDROLOGY OF RANGELANDS IN THE NORTHWEST

See Water Resources Research Catalog **6,** 7.0093.

303-05209-840-00

DEVELOPMENT OF IMPROVED SURFACE IRRIGATION SYSTEMS (Formerly, Structures and Techniques for Irrigation Water Control and Measurement.)

(*c*) A. S. Humpherys, Agr. Engr., Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho.
(*d*) Experimental, field investigations; applied research and development.
(*e*) Develop improved surface systems for the control and application of irrigation water. Devices, structures and techniques for manual, semiautomatic and automatic application of irrigation water will be developed to enable more efficient use of farm water supplies and reduce soil erosion and sedimentation. Structures and devices are tested in the laboratory and the field to determine their hydraulic characteristics and to evaluate the design, performance and adaptability to field conditions. Complete systems will be field tested to evaluate their water and labor requirements and ability to control erosion.
(*g*) Timer-controlled gates and checks have reduced labor requirements from one-third to as much as one-fifteenth of their former value with conventional systems. Drop-closed and drop-open gates in various configurations have been developed and tested. An automatic cutback furrow system can save both labor and water, however, the design is quite rigid and the system must be operated as designed. Low pressure, water-inflated valves for irrigation pipeline systems have been tested in the laboratory and in two field installations. Flow is controlled by inflation and deflation of the valves with mechanical timers.
(*h*) **Automatic Furrow Irrigation System,** A. S. Humpherys, *Trans. ASAE* **14,** 3, 466-470, May-June 1971.
Auto-Mechanization of Open Channel Distribution Systems, A. S. Humpherys, J. E. Garton, E. G. Kruse, *Proc. ASAE Natl. Irrigation Symp.*, Lincoln, Nebr., Nov. 1970, p. L-1 to L-20.
Field Evaluation of Drop-Check Structures for Farm Irrigation Systems, A. S. Humpherys, A. R. Robinson, *ARS 41-180*, Mar. 1971, 42 p.

303-08434-820-00

REGIONAL WATER MANAGEMENT STUDY–JEFFERSON COUNTY, IDAHO

(*c*) James A. Bondurant, Agr. Engr., USDA-ARS-SWC, Route 1, Box 186, Kimberly, Idaho.
(*d*) Theoretical and field investigation; applied research.
(*e*) Numerous complex irrigation water management problems exist in the older irrigation projects of the Western U.S. where unlined, multiple canal systems are operated by numerous small canal companies. Typical problems involve high diversion requirements because of high seepage losses accompanied by high groundwater levels. Progress toward modernizing the delivery systems and solving these problems is hampered by lack of local incentives, finances, methods and authorities for consolidating multiple canal systems, methods for reducing system losses, and on-farm water management practices that have not changed in decades. The purpose of this study is to develop a general systematic method of evaluating the major causes of the project-wide problems and to develop general mathematical models that can be used to evaluate alternative solutions or corrective measures. The primary problem encountered in this area of study involves high groundwater levels that annually result in extensive property damage.
(*g*) All historical water diversion and groundwater data have been collected. Water table elevations, canal diversions, farm deliveries and farm irrigation efficiencies are being determined over a 3-year period. A digital computer

model of the groundwater system in the area has been completed and is being calibrated. This model will be used to study the effects of reducing seepage losses and modifying river management and irrigation practices.

(*h*) **Development of Mathematical Groundwater Model,** J. L. J. deSonneville, *M.Sc. Thesis*, C. E. Dept., Univ. of Idaho, Moscow, Idaho 1972.

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHERN BRANCH, P.O. Box 1072, Athens, Ga. 30601. Dr. G. R. Burns, Branch Chief.

304-03871-220-00

SEDIMENT TRANSPORT IN STREAM CHANNELS

(Also listed in Water Resources Research Catalog **6**, 2.0930)

(*b*) Cooperative with the University of Mississippi and Mississippi State University.

(*c*) Messrs Joe C. Willis and A. J. Bowie, Hydraulic Engrs., and Dr. Neil L. Coleman, Geologist, USDA Sedimentation Lab., P.O. Box 30, Oxford, Miss. 38655.

(*d*) Experimental; basic and applied research.

(*e*) Investigate all aspects of sediment transport including "wash load," bed load, suspended load, bed material transport, and total sediment transport in alluvial channels. Determine by laboratory and field experiments the effects of flow characteristics, physical properties of bed forms and bed material on sediment transport in alluvial channels. Design, develop and test instruments and techniques for measurement of water runoff and sediment discharge.

(*g*) Relationships for the transport of fine sand bed material were developed that permit the average discharge concentration of sediment to be predicted from a knowledge of the flow depth and the flow discharge per unit of channel width. A sediment concentration is uniquely specified by the Froude number of the flow for flow depths equal to or less than 0.7 ft. and the deviation from this relationship for deeper depths is probably not general but due to the limited flume length and low fall velocity of the sediment particles.

A relationship has been developed between the concentration of sediment derived by erosion by shallow flows from a given length of channel bed and the excess Froude number over the critical Froude number for sediment motion. The experimental data define the critical Froude number as a function of the Reynolds number of the flow and the properties of the sediment.

A method for calculating the total sediment transport rate from two or more point measurements of concentration and velocity has been derived and verified by flume data. The method is based on a mathematical model for the vertical distribution of the sediment flux which arises from continuity considerations and an analog between the diffusion of sediment momentum and the diffusion of fluid momentum. Evaluation of the integral of this model over the flow depth gives values that agree closely with total sediment load measurements.

Experimental data indicate that for flows ranging in depth from 0.03 ft. to 0.30 ft., the bed load transport is a second power parabolic function of bed shear stress when the bed consists of sand having a median dia. of 0.40 mm. Though much difficulty may be encountered in the numerical evaluation of the terms used in the equation, the relationship described above strongly supports the use of an equation of the DuBoys type for computation of bed material transport. For flows ranging in depth from 0.03 ft. to 0.30 ft., unique relationships exist between discharge and concentration for a given depth or a given slope.

(*h*) **Flume Studies of the Sediment Transfer Coefficient,** N. L. Coleman, *Water Resour. Res.* **6**, 3, pp. 801-809, 1970.

An Error Function Description of the Vertical Suspended Sediment Distribution, J. C. Willis, *Water Resour. Res.* **5**, 6, pp. 1322-1329, 1969.

Unification of Flume Sediment Discharge Data by Similitude Principles, J. C. Willis, N. L. Coleman, *Water Resour. Res.* **5**, 6, pp. 1330-1336, 1969.

Effect of Sediment Concentration Gradients on the Performance of a Nuclear Sediment Concentration Gauge, J. R. McHenry, N. L. Coleman, J. C. Willis, A. C. Gill, O. W. Sansom, B. R. Carroll, *J. Water Resour. Res.* **6**, 538-548, 1970.

Mathematical Models for Sediment Suspension from a Momentum Diffusion Viewpoint, J. C. Willis, *Sedimentation* (*Einstein*), Ch. 9, pp. 9-1–9-22. (Proc. Symp. to Honor Prof. Hans A. Einstein, Univ. of Calif. Berkeley, June 17-19, 1971, published by Hsieh Wen Shen, Colorado State University, 1972.)

Reply—to comments on "Flume Studies of the Sediment Transfer Coefficients' by U. A. Rao, *Water Resour. Res.* **6**, 3, 1969, by N. L. Coleman, *Water Resour. Res.* **7**, 3, pp. 751-752, 1971.

Discussion: 'Indeterminate Hydraulics of Alluvial Channels' by Thomas Maddock, Jr., *Proc. Paper 7696*, *J. Hydr. Div.*, *ASCE* **96**, HY11, Nov. 1970, J. C. Willis, *Proc. Paper 8223*, *J. Hydr. Div.*, *ASCE* **97**, HY7, pp. 1129-1163, 1971.

A Laboratory Study of the Transport of Fine-Grained Sand, J. C. Willis, N. L. Coleman, W. M. Ellis, *J. Hydr. Div.*, *ASCE* **98**, HY3, Proc. Paper 8765, pp. 489-501, Mar. 1972.

The Speeds of Sand Grains in Laminar Flow Over a Smooth Bed, D. A. Parsons, *Sedimentation* (*Einstein*), Ch. 1, pp. 1-1–1-25. (Proc. Symp. to Honor Prof. Hans A. Einstein, Univ. of Calif., Berkeley, June 17-19, 1971, published by Hsieh Wen Shen, Colorado State University, 1972.)

Discussion: 'Bed Load Transportation in Alluvial Channels' by S. P. Garg, A. K. Agrowal, and Prem Raj Singh, *Proc. Paper 8091*, *J. Hydr. Div.*, *ASCE* **97**, HY5, May 1971, by W. C. Harmon, *J. Hydr. Div.*, *ASCE* **98**, HY1, pp. 291-295, Jan. 1972.

304-04316-300-00

DESIGN CRITERIA FOR WATER CONTROL STRUCTURES AND CHANNEL STABILIZATION

(Also listed in Water Resources Research Catalog **6**, 8.0353.)

(*b*) Cooperative with the University of Mississippi, Mississippi State University, and the Soil Conservation Service.

(*c*) Mr. A. R. Robinson, Hydraulic Engineer and Director, and Dr. Neil L. Coleman, Geologist, USDA Sedimentation Laboratory, Box 30, Oxford, Miss. 38655.

(*d*) Field and laboratory investigations; basic and applied research.

(*e*) Develop and evaluate techniques and criteria for the design, stabilization, and maintenance of stream channels. Investigate by model and field studies methods and means of channel stabilization and protection. Areas of investigation include the influence of plan geometry and channel shapes; the spectrum of flood flow values; flow velocities, depths, and slopes; flow reduction schemes; and the use of engineering works, vegetation, etc., to reduce channel boundary velocities and protect the channel lining.

(*g*) Channel bend studies in a laboratory flume show that the boundary shear can be reduced in certain areas by changing the geometry of the curved portion of the channel. This fact suggests the possibility that more efficient bends may be designed and built into man-made channels, thus reducing the erosion potential of the flow in these critical areas. It was also shown that superelevation of the water surface can be greatly reduced by bend design.

The streambank protective measures on the South Branch of Tillatoba Creek, Mississippi have been in place from 4 to 5 years and have experienced two large floods that were probable maximums for 5-1/2 and 12 years. Estimated average velocities ranged up to 10 feet per second for the larger flood. The flood effects in the 24 protected channel bends indicated that the cabled concrete jacks, the cabled automobile bodies, and the piling and waling fences were sufficiently strong, with few exceptions, to withstand the forces of the floods. It was also demonstrated with only two exceptions that the points of beginning at the upstream ends of the structures were properly chosen. The choices of alignment and extent of the revetment in the downstream direction were also generally good; however several cases of severe bank erosion in these areas are cause for reservation in regard to adequacy.

The principal deficiency, other than the inadequate protection at the ends of the structures in a few instances, was the lack of sufficient protection for the upper bank. With high-speed flood waters flowing as much as 9 feet deep over the top of the revetment structures the upper portions of the banks were vulnerable and were eroded in many places. This points up the need for estimates of flood magnitudes, stages, and frequencies as a part of the design procedure.

(*h*) **Model Study of Scour from Cantilevered Outlets,** A. R. Robinson, *Trans. ASAE* **14,** 3, pp. 571-576, May-June 1971.

Analyzing Laboratory Measurements of Scour at Cylindrical Piers in Sand Beds, N. L. Coleman, *IAHR Proc.* **3, 14th Congr. IAHR-C-37,** Aug.-Sept. 1971, Paris, France, pp. 307-313, 1971.

Discussion: 'Hydrologic Effects of Seepage on Bed Particles' by G. Z. Watters and M. V. P. Rao, *Proc. Paper 7973, J. Hydr. Div., ASCE,* by N. L. Coleman, *J. Hydr. Div. ASCE* **97,** HY11, pp. 1921-1922, Nov. 1971.

304-04317-300-00

STREAM CHANNEL MORPHOLOGY AND STABILITY

(Also listed in Water Resources Research Catalog **6,** 2.0938.)

(*b*) Cooperative with the University of Mississippi and Mississippi State University.

(*c*) Dr. Earl J. Grissinger, Soil Scientist, Dr. Neil L. Coleman, Geologist, and Mr. A. R. Robinson, Hydraulic Engineer and Director, USDA Sedimentation Laboratory, P.O. Box 30, Oxford, Miss. 38655.

(*d*) Experimental; applied and basic research.

(*e*) Investigations of prevailing horizontal and vertical forms of stream channels and the processes and forces that create them, including bed forms and resistance to flow in alluvial channels, to acquire knowledge that will provide engineering solutions to problems of channel stability. Determine from both laboratory and field experiments the effects of various hydraulic and mineralogical parameters on channel geometry and stability; also the influences of horizontal channel geometry on the flow parameters. The latter are interdependent. Hydraulic parameters include velocity head, boundary shear stress, Froude and Reynolds numbers, and hydraulic gradient. The inherent and the environmental factors affecting cohesiveness of channel periphery materials will be investigated.

(*g*) The USDA Sedimentation Laboratory at Oxford, Miss., in cooperation with the Northern Plains Branch and the Soil Conservation Service found that median values for recognized indicators of flow erosivity in the expected peak flow each year for a stable channel condition in small waterways in Southeastern Nebraska are 0.44 lbs/sq.ft. for tractive force; 1.45 lbs/ft-sec for tractive power; 0.15 ft. for velocity head ($V = 3.1$ ft/sec); and 0.48 for Froude number, $V/(gD)^{1/2}$. Also, a new flow erosivity function $U = S(Q/w)^{1/2}$ is introduced, involving slope, flow and wetted perimeter, which has a median 1-yr. flood value of 0.0115. A watershed function for the same purpose, $Y = S(D.A.)^{0.4}$, involving the energy slope of the 1-year flood and the drainage area in acres is also introduced. It has a median value of 0.064.

Of the many features of the waterways that were observed and measured only the pH was thus far found to have a consistent association with stability, increasing with increasing stability. For example, the average velocity for a stable channel increased from 3.1 ft/sec to 3.6 ft/sec with a change in pH from 6.5 to 7.5.

Contrary to accepted thinking, channel stability is not enhanced by an increase in the width-depth ratio. Rather, the width-depth ratio is somewhat dependent upon the phase of the degradation and valley forming process. The practice of reshaping small waterways is apparently successful because of its smoothing and vegetative aspects rather than the spreading of the flow to obtain a larger width-depth ratio and lower velocity.

The median value of the ratio of the energy gradient of the flow to the slope of the valley is 0.8. Although this is the central value tending to divide the study reaches between those that aggrade and those that degrade, they actually vary at this ratio from one extreme to the other.

Definition of the influence or influences of cohesive variables on soil stability requires a prior definition of the functional relationships between stability and environmental variables. The environmental variables include aging time, water temperature, sample water content at the initiation of the erosive test, and changes in the sample water content. Investigations of possible functional relationships between measured erosion rates and environmental variables were attempted using a least squares analysis. Regression coefficients of erosion rate on P ln (rate of water change in the sample) were significant for most but not all samples. Each regression was calculated from data of varying bulk density and antecedent water content. In this empirical relation P is the void volume/total sample volume. Studies attempting to correlate the regression coefficients with selected soil properties are in progress.

(*h*) **Erosion by Concentrated Flow,** J. C. Willis, *ARS 41-179,* Feb. 1971.

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division

SOUTHERN PLAINS BRANCH, Bushland, Tex. 79012. Dr. J. R. Johnston, Branch Chief.

305-0203W-830-00

SEDIMENT YIELD IN RELATION TO WATERSHED FEATURES IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6,** 2.1175.

305-0204W-810-00

SYNTHESIS OF STREAMFLOW REGIMES IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6,** 2.1176.

305-0205W-810-00

HYDROLOGIC PERFORMANCE OF AGRICULTURAL LANDS IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6,** 2.1177 and 2.1180.

305-0206W-810-00

PRECIPITATION PATTERNS ON UPSTREAM WATERSHEDS IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6**, 2.1179.

305-0207W-810-00

STREAMFLOW REGIMES OF AGRICULTURAL WATERSHEDS IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6**, 2.1181.

305-0208W-810-00

RUNOFF AND STREAMFLOW REGIMES OF AGRICULTURAL WATERSHEDS IN THE WESTERN GULF REGION

See Water Resources Research Catalog **6**, 2.1366.

305-0209W-810-00

SEDIMENT YIELD IN RELATION TO WATERSHED FEATURES IN THE WESTERN GULF REGION

See Water Resources Research Catalog **6**, 2.1367.

305-0210W-830-00

WATER EROSION CONTROL PRACTICES FOR THE TEXAS BLACKLAND PRAIRIE

See Water Resources Research Catalog **6**, 2.1377.

305-0211W-820-00

PRINCIPLES, FACILITIES AND SYSTEMS FOR GROUNDWATER RECHARGE–SOUTHERN PLAINS

See Water Resources Research Catalog **6**, 4.0261.

305-0212W-300-00

STREAM CHANNEL MORPHOLOGY IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6**, 2.1178.

305-0213W-810-00

PRECIPITATION PATTERNS ON UPSTREAM WATERSHEDS IN THE WESTERN GULF REGION

See Water Resources Research Catalog **6**, 2.1368.

305-0214W-810-00

HYDROLOGIC PERFORMANCE OF AGRICULTURAL LANDS IN THE WESTERN GULF REGION

See Water Resources Research Catalog **6**, 2.1369.

305-0215W-810-00

PREDICTING RUNOFF AND STREAMFLOW FROM AGRICULTURAL WATERSHEDS IN THE WESTERN GULF REGION

See Water Resources Research Catalog **6**, 2.1376.

305-0216W-830-00

SEDIMENT YIELD IN RELATION TO WATERSHED AND CLIMATIC CHARACTERISTICS IN THE WESTERN GULF REGION

See Water Resources Research Catalog **6**, 2.1379.

305-0217W-830-00

WATER EROSION PROCESSES IN RELATION TO WIND IN THE GREAT PLAINS

See Water Resources Research Catalog **6**, 4.0153.

305-0218W-820-00

GROUNDWATER IN RELATION TO USE AND MANAGEMENT OF WATERSHEDS IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6**, 4.0222.

305-0219W-820-00

GROUNDWATER IN RELATION TO USE AND MANAGEMENT OF WATERSHEDS IN THE WESTERN GULF REGION

See Water Resources Research Catalog **6**, 4.0271.

305-0220W-820-00

EFFECT OF WATERSHED CHARACTERISTICS AND MANAGEMENT ON WATER SALINITY

See Water Resources Research Catalog **6**, 5.1187.

305-0221W-810-00

REMOTE SENSING FOR SPECTRAL ANALYSIS OF HYDROLOGIC VARIABLES IN THE SOUTHERN PLAINS

See Water Resources Research Catalog **6**, 7.0177.

305-04337-320-00

HYDROMECHANICS OF OVERLAND, CHANNEL AND FLOODPLAIN FLOWS

(*b*) Cooperative with the Oklahoma Agricultural Expmt. Station.
(*c*) Mr. W. O. Ree, Engineer in Charge, P.O. Box 551, Stillwater, Okla. 74074.
(*d*) Experimental; applied research.
(*e*) Obtain data needed for the design of channels used in soil and water conservation works, for testing theories of the hydromechanics of surface flow, and for developing hydraulic explanations of hydrologic phenomena. Experimental channels are built on the laboratory grounds, planted to grasses or lined with artificial materials and then subjected to controlled flows of water. Test flows can be steady or unsteady, uniform or nonuniform, or in one channel, can be spatially varied as well. Flow retardance coefficients, permissible velocities, energy and momentum coefficients, and flow profiles are determined. (Also listed in Water Resources Research Catalog **6**, 2.1191.)
(*g*) Manning's n values for vegetation lined channels are a function of depth and velocity of flow as well as the physical characteristics of the vegetation. Permissible velocities are influenced by the physical characteristics of the vegetal cover, the textures of the soil, and by the steepness of the channel. Permissible velocity and n-value data are given in a handbook of channel design prepared by the laboratory. Spatially varied flow equations now in use can predict flow profiles accurately only if realistic momentum coefficients are used.

305-7002-390-00

DEVELOPMENT AND HYDRAULIC TESTING OF CONSERVATION STRUCTURES AND WATERFLOW MEASURING DEVICES

See U.S. Department of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Division, Cornbelt Branch, Project 01723.

(*b*) Cooperative with the Oklahoma Agric. Exp. Station.
(*c*) Dr. W. R. Gwinn, Hydraulic Engineer, P.O. Box 551, Stillwater, Okla. 74074.
(*d*) Experimental, applied research.
(*e*) Develop and test hydraulic structures for soil and water conservation works. Test small-scale and full-size models of structures and appurtenances in laboratory basins. Determine general hydraulic performance, head loss coefficients, pressure coefficients and related hydraulic phenomena. Structures required for flow measurement in

the hydrology research program of the Agricultural Research Service, U.S. Department of Agriculture, are developed for sites where standard structures are not practical. Such sites include steep sand-laden streams and streams having very flat gradients. Consideration is given to scour, backwater and channel control effects. Modifications to existing drainage structures to make them suitable for runoff measurement are devised and tested. (Also listed in Water Resources Research Catalog **6**, 6.0179, 7.0180, and 8.0455.)

(*g*) Trash racks on closed conduit spillways for floodwater retarding reservoirs have been tested with clear water flows and with flows carrying hay or sticks. Relative efficiencies of various rack designs have been determined. A complex of channels and structures comprising an urban floodwater disposal system has been tested. Nine large supercritical flow measuring flumes with capacities up to 22,500 cfs have been designed and calibrated. Eight highway culverts equipped with V-notch weirs have been calibrated. Model studies of two highway bridge sites have been made to determine the effect of the addition of weirs for low flow measurement. Protection of the bridge foundations from scour was a consideration.

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHWEST BRANCH, P.O. Box 2326, Riverside, Calif. 92506. Mr. E. E. Haskell, Branch Chief.

306-0222W-840-00

IRRIGATION AND EVAPOTRANSPIRATION OF WATER BY CROPS IN IMPERIAL VALLEY

See Water Resources Research Catalog **6**, 2.0192.

306-0223W-840-00

DRAIN DESIGN FOR NITRATE REDUCTION IN GROUNDWATER

See Water Resources Research Catalog **6**, 5.0115.

306-0224W-840-00

DRAINAGE SYSTEMS FOR THE IMPERIAL VALLEY

See Water Resources Research Catalog **6**, 8.0046.

306-0225W-820-00

RELATION OF SALINITY TO STATE AND TRANSPORT OF WATER AND IONS IN SOIL AND PLANTS

See Water Resources Research Catalog **6**, 1.0014.

306-0226W-820-00

GROUNDWATER RECHARGE AND MANAGEMENT IN CALIFORNIA

See Water Resources Research Catalog **6**, 4.0044.

306-0227W-810-00

CLIMATE, SOIL AND VEGETATION INFLUENCES ON HYDROLOGY OF RANGELANDS IN THE SOUTHWEST

See Water Resources Research Catalog **6**, 2.0045.

306-0228W-810-00

STREAM FLOW REGIMES OF SEMIARID RANGELAND WATERSHEDS IN THE SOUTHWEST

See Water Resources Research Catalog **6**, 2.0046.

306-0229W-810-00

PRECIPITATION PATTERNS ON RANGELAND WATERSHEDS IN THE SOUTHWEST

See Water Resources Research Catalog **6**, 2.0047.

306-0230W-300-00

FLOOD WAVE MOVEMENT IN NATURAL EPHEMERAL STREAM CHANNELS

See Water Resources Research Catalog **6**, 2.0048.

306-0231W-830-00

SEDIMENT YIELD FROM RANGELAND WATERSHEDS IN THE SOUTHWEST

See Water Resources Research Catalog **6**, 2.0049.

306-0232W-810-00

PREDICTING RUNOFF AND STREAM FLOW FROM WATERSHEDS IN THE SOUTHWEST

See Water Resources Research Catalog **6**, 2.0050.

306-0233W-820-00

GROUNDWATER IN RELATION TO USE AND MANAGEMENT OF RANGELAND WATERSHEDS IN THE SOUTHWEST

See Water Resources Research Catalog **6**, 4.0010.

306-0234W-820-00

SOIL WATER MOVEMENT IN RELATION TO THE CONSERVATION OF WATER SUPPLIES

See Water Resources Research Catalog **6**, 3.0004.

306-0235W-840-00

EFFICIENT IRRIGATION AND AGRICULTURAL WATER USE

See Water Resources Research Catalog **6**, 3.0005.

306-0236W-860-00

INCREASING AND CONSERVING FARM WATER SUPPLIES

See Water Resources Research Catalog **6**, 3.0006.

306-0237W-860-00

EVALUATION AND CONTROL OF SEEPAGE FROM WATER STORAGE AND CONVEYANCE STRUCTURES

See Water Resource Research Catalog **6**, 4.0007.

306-0238W-810-00

SUPPRESSION OF EVAPORATION FROM WATER SURFACES

See Water Resources Research Catalog **6**, 4.0008.

306-0239W-860-00

PRINCIPLES, FACILITIES, AND SYSTEMS FOR WATER HARVEST

See Water Resources Research Catalog **6**, 4.0009.

306-0240W-860-00

METHODS FOR WATER QUALITY IMPROVEMENT AND ITS STORAGE UNDERGROUND

See Water Resources Research Catalog **6**, 5.0059.

306-0241W-840-00

IRRIGATION SYSTEMS FOR EFFICIENT WATER USE

See Water Resources Research Catalog **6**, 8.0004.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION, Ogden, Utah 84401. Robert W. Harris, Director.

307-06968-830-00

SOIL EROSION AND CONTROL

(*d*) Laboratory and field investigations, basic and applied research.

(*e*) Develop watershed protection requirements for important soil-vegetation complexes in the Intermountain and Northern Rocky Mountain Regions.

(*g*) Soil, rainfall, and topographic variables were related to soil erosion caused by overland flow and by raindrop splash separately. Multiple regression models were developed for both sheet erosion from overland flow and splash erosion from raindrops. The variables having the greatest influence on erosion by overland flow are rainfall intensity, slope steepness, and the proportion of the soil in particles greater than 2 mm. in diameter. Variables having the most influence on raindrop splash erosion are rainfall intensity, slope steepness, proportion of the soil between 60 and 2,000 microns in diameter, and soil bulk density. The influences of rainfall intensity and slope steepness on soil erosion are at least a full order of magnitude greater than the effects of any soil variable.

The amount of soil eroded from high-elevation range sites in the Intermountain area was measured under the impact of a fixed amount of simulated rain. Under these conditions, erosion is more closely related to the amount of cover than to any other site characteristic. However, the relation between erosion and cover is strongly influenced by slope gradient. Regression analyses indicate that erosion is about the same on a 5 percent slope with 40 percent cover as it is on a 35 percent slope with 80 percent cover. Organic matter is the most important soil parameter affecting erodibility, but the direction and magnitude of its effects depend on soil texture. Organic matter decreases erosion of clay soils but tends to increase erosion of sandy soil.

Water repellency is common in the granitic soils in the Carson Range of the Sierra Nevada, and can be a major limiting factor in the capacity of these soils to absorb high-intensity summer rainfall. Results of infiltrometer tests indicate that water repellency often impedes infiltration under pine litter but rarely does so under chaparral cover. Water repellency tends to develop in a continuous layer at the soil surface under pine litter. Fortunately, this layer is usually disrupted by root channels, rodent burrows, and other biologic activities; allowing water to penetrate at a few points and spread out into the wettable subsoil. Patches of water-repellent soil are often found under chaparral, but no tendency for the development of a continuous repellent layer has been detected.

(*h*) **Soil Erosion by Overland Flow and Raindrop Splash on Three Mountain Soils,** E. E. Farmer, B. P. Van Haveren, *USDA Forest Serv. Res. Paper INT-100*, 1971.

Soil Stability on High-Elevation Rangeland in the Intermountain Area, R. O. Meeuwig, *USDA Forest Serv. Res. Paper INT-94*, 1971.

Infiltration and Water Repellency in Granitic Soils, R. O. Meeuwig, *USDA Forest Serv. Res. Paper INT-111*, 1971.

307-06969-810-00

SNOWPACK HYDROLOGY

(*d*) Field investigation, basic and applied research.

(*e*) Snowpack is being studied in Utah and in northern Idaho for the applied objective of water yield improvement. The particular research reported here pertains to snowmelt magnitude and distribution as affected by terrain and cover variables in a western white pine forest in northern Idaho.

(*g*) Whether increases in snowpack water that result from cutting timber in western white pine forests of the Northern Rocky Mountains can create flood-producing conditions depends, in part, upon the melting behavior of the snowpack under various terrain and forest conditions. Results of a 4-year study show that snowmelt (ablation) rates are influenced significantly by differences in terrain and forest cover conditions. Differences in elevation, aspect, slope steepness, and forest cover accounted for 74 percent of the variance in snowmelt rates.

Forest managers can exert some control over snowmelt rates by choosing the terrain and forest cover conditions suitable for specific forest management practices. For instance, clearcutting of the most dense forest stands on southerly aspects at low-to-intermediate elevations provides largest increases in snowmelt rates. On the other hand, partial cutting of timber on northerly aspects at intermediate-to-high elevations affords the best opportunity to effect reductions in snowmelt rates.

The pump-manometer is an instrument that provides a way to quickly and accurately measure hydraulic conductivity in the field by means of either the auger-hole method or the piezometer method. This device can be operated easily by a two-man crew, but, with practice, one man can perform the entire operation. The particular advantage of the pump-manometer is that measurement of the rate of rise of water can begin as soon as the well is pumped dry without having to remove a pump from the well and then insert a manometer.

(*h*) **Terrain and Cover Effects on Snowmelt in a Western White Pine Forest,** P. E. Packer, *Forest Sci.* **17**, 1, 125-134, 1971.

A Pump Manometer for Groundwater Studies, B. Z. Richardson, E. R. Burroughs, Jr., *USDA Forest Serv. Res. Note INT-137*, 1971.

307-08435-810-00

SUBSURFACE FLOW

(*d*) Field investigation, basic and applied research.

(*e*) Evaluation of the effects of road construction and timber cutting on subsurface flow on slopes in the mountains of central Idaho is underway. Coarse-textured, relatively shallow soils; steep slopes; granitic bedrock with relatively low hydraulic conductivity; and large volume water inputs from snowmelt and/or large cyclonic storms are all conducive to the generation of subsurface flow. Road construction often incises the subsurface flow level, transforming subsurface to surface flow. This may interrupt the hydrologic function of the watershed containing the road, and has ecologic implications as well. Two micro-watersheds of 0.8 and 2.4 acres in size have been instrumented. Instrumentation includes a climatic station; snow lysimeters; a network of snow stakes, soil moisture access tubes and piezometers; and surface and subsurface flow measuring apparatus.

(*g*) No overland flow has been measured on either study watershed at any time. Subsurface flows occurred only during periods of large volume water inputs to the soils, and was restricted to the spring snowmelt periods during 1970 and 1971. Maximum flows occurred during 1971 with a high instantaneous peak of 20.1 cubic feet per second per square mile, and a total volume of 8.4 inches per unit area of watershed. Flows varied slightly between watersheds, but were vastly different between years. Yearly differences were related to amounts and rates of inflow. A comparison of nearby perennial watersheds suggests that the weathered and fractured granitic bedrock is more hydrologically active than previously thought. Interception of overland flow by roads is considerably greater than the flow generated by overland flow from the road surface itself.

307-08436-810-00

FOREST PRACTICE EFFECTS

(*d*) Field investigation, basic and applied research.

(*e*) Watershed studies of the effects of logging and road construction on sediment production are presently in progress on 12 forested watersheds in the Idaho Batholith of central Idaho. These undisturbed watersheds are now being calibrated. Sediment is collected in small retention reservoirs twice a year; in the spring after the peak snowmelt period and in the fall near the end of the water year. A study was completed recently to predict the volume weight of sediment deposited in reservoirs based on the particle size of lithic sediments and the percentage of organic sediments.

(*g*) Volume weights of sediment deposited in small retention reservoirs vary considerably among the various watersheds and within a given impoundment. The percentage of organic matter by weight in the samples provided a reliable basis for estimating sediment volume weight–better than the more conventional approach of relating volume weight to sediment particle size. The organic content of sediment can result in substantial loss of sediment volume for reservoirs on forested watersheds.

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U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, NORTH CENTRAL FOREST EXPERIMENT STATION, Folwell Avenue, St. Paul, Minn. 55101. F. Bryan Clark, Acting Director.

308-03887-810-00

WATERSHED MANAGEMENT RESEARCH IN NORTHERN MINNESOTA

(*c*) D. H. Boelter, USDA, Forest Service, North Central Forest Experiment Station, Grand Rapids, Minn. 55744.

(*d*) Experimental and field investigation; basic and applied research.

(*e*) Use basic hydrologic studies to develop management practices that will maintain or improve the quality and quantity of water yields from northern forest lands. Forest cultural practices (including timber harvesting, fertilization, use of herbicides, and prescribed burning) are studied to determine their effect on the water resources of northern conifer-hardwood forests. Of special concern will be the complex associations of uplands and bogs common to these forests. Methods will be developed for sampling and analyzing both surface and subsurface flows from treated areas. Wetland impoundments developed for wildlife habitat or cultural purposes will be monitored and management techniques developed to minimize their effect on water quality factors such as temperature and nutrient content. Sewage disposal on organic soil and adjacent upland sites will be tested to determine if these sites can be used for waste disposal without impairing the quality of the associated water resources.

(*g*) Some people regard bogs as important water storage areas, yet data collected during a 6-year calibration period on five experimental bogs show that two-thirds or more of the average annual runoff occurs before June 1. Many bogs are not long-term water storage areas. Storm flow data, however, indicate that bogs may be important as short-term storage areas because individual storm peaks are low and storm recessions tend to be prolonged. Attempts at water level control in organic soils using open ditches show that effective control requires intensive drainage systems. In partially decomposed peat materials, an open ditch had little influence on the water table 20 to 30 feet from the ditch.

(*h*) **Important Physical Properties of Peat Materials,** D. H. Boelter, *3rd Intl. Peat Congr.*, Quebec, Proc. 1968; 150-154, 1970.

The Hydrology of Several Peat Deposits in Northern Minnesota, U.S.A., R. R. Bay, *3rd Intl. Peat Congr.*, Quebec, Proc. 1968; 212-218, 1970.

Water Resources Research in Minnesota by the North Central Forest Experiment Station, USDA Forest Service, R. R. Bay, Conf. on Ongoing Water Resour. Res. in Minn. Proc., *Water Resour. Res. Center Bull. 21*, 50-56, 1970.

Vegetative Influences of the Diurnal and Seasonal Availability of Solar Energy of Peatlands, E. R. Berglund, *Ph.D. Dissertation*, Univ. Minn., 144 p., 1970.

Water Table Relationships on Experimental Basins Containing Peat Bogs, R. R. Bay, *IASH (Unesco) Publ. 96*, 360-368, 1970.

Bog-Watershed Relationship Utilizing Electric Analog Modeling, J. E. Sander, *Ph.D. Dissertation*, Mich. State Univ., 225 p., 1971.

Economical Conversion of a Miniature Net Radiometer to an All-Wave Hemispheric Radiometer, J. M. Brown, *USDA Forest Serv. Res. Note NC-123, 2 p., 1971.*

308-03889-810-00

WATERSHED MANAGEMENT RESEARCH IN THE DRIFTLESS AREA OF SOUTHWESTERN WISCONSIN

(*b*) Some aspects of project in cooperation with Wisconsin Conservation Department.

(*d*) Field investigations; basic and applied research.

(*e*) Research is conducted on the influence of both natural and planted forests on runoff and erosion (particularly with regard to spring-thaw floods) and hydrologic effects of soil freezing. The study of forest-land gullies and the reduction of gullying by spreading upland runoff into the lower lying forest zone is included. Overland flow is measured by flumes and recorders at 20 stations, either on natural runoff plots or small watersheds. Factors affecting springflow are also under study. Springflow is measured at 2 stations by weirs and recorders. In addition, a number of wells are measured, one with a water level recorder.

(*g*) Storm flow from dual-use watersheds was studied by comparing flows from upland fields with outflows at the bottom of the wooded slopes below. Most upland flows never reached the bottom of the forested slopes. In general, larger upland flows produced larger lower station flows, but there were many exceptions. Mean proportions of lower station to upland runoff for large storms ranged from 56 to 94 percent. Sediment content was higher at lower than at upper stations. The effectiveness of the forest zone in disposing of upland runoff appeared to be related to the ratio of forest to upland area.

Sampling errors were determined for neutron meter measurements of soil water content in a heterogeneous forest soil. Water content changes over a period of time were more variable than water content at a single point in time. Coefficients of variation for individual depths ranged up to 76 percent for uncut plots and up to 137 percent for cut plots. Coefficients of variation for total profile storage were a little lower for change in water content than for total water content on uncut plots, but the relationship was reversed on cut plots. Soil depth differences contributed substantially to the variance of total storage changes.

Infiltration rate in a frozen Fayette silt loam soil under three cover conditions was measured with tin can infiltrometers and an antifreeze solution. Prefreeze infiltration rate was similar for all cover conditions. In deciduous forest and abandoned field plots, soil freezing did not change the infiltration rate sharply until late winter when infiltrating snowmelt and rainfall froze in the soil pores. In a conifer plantation, the infiltration rate was nearly zero in early winter due to an impermeable snow-ice layer caused by snowmelt drip from the tree canopy. Because of large macropores, infiltration rates were high on the deciduous forest and abandoned field plots even when the frozen soil contained nearly 50 percent water by volume.

(*h*) **Effect of Land Use on the Hydrology of Small Watersheds in Southwestern Wisconsin,** R. S. Sartz, *IASH (Unesco) Publ. 96*, 286-295, 1970.

Storm Flow From Dual-Use Watersheds in Southwestern Wisconsin, R. S. Sartz, *USDA Forest Serv. Res. Paper NC-69*, 7 p., 1971.

Infiltration Rate as Affected by Soil Freezing Under Three Cover Types, A. R. Harris. (Manuscript accepted by *Soil Sci. Soc. Am. Proc.* for publication in 1972.)

308-03890-810-00

WATERSHED MANAGEMENT RESEARCH IN LOWER MICHIGAN

(*d*) Field investigation; basic and applied research.

(*e*) Measuring groundwater recharge and evapotranspiration in conifer forests under 50 percent cut, clearcut, and fully stocked stands, and measurement of the effects of sediment on trout-stream habitat conditions. Groundwater levels are being measured on extensive and intensive plot studies to relate water-table elevations to groundwater recharge and comparative evapotranspiration of conifer, hardwoods, and partial and clearcut stands. Snow accumulation studies are in progress in relation to clearcutting patterns in outwash plain pine plantations. Changes in stream cross-section and bed material composition are being related to fish populations changes in a stream where daily input of artificially added sediment is producing a sediment wave propagating slowly downstream. Streambed temperatures, groundwater inflow, oxygen concentrations, and streambed texture are being related to spawning success of brown trout. Supplemental studies of groundwater pollution from irrigation of forest lands with secondary municipal sewage effluent are in progress.

(*g*) During the 4 years following removal of 50 percent of the trees from a jack pine plantation, approximately 3 inches of additional groundwater recharge occurred. The effect of cutting was reduced rapidly during this period. The low morainal hills in the research area measurably increased the amount of snow squall precipitation on the lee slopes. Artificial sills placed in the streambed enabled "total sediment load" to be measured with a DH-48 hand sampler. Most of the total load increase along a 26-mile main channel section was due to streambank erosion. Three-fourths of the sediment was sand size. There was evidence that transporting capacity of the stream exceeded sediment supply; therefore streambank stabilization would produce relatively rapid changes in bed-material sediments. Applying 64 inches at 2.5 inches per week of chlorinated municipal sewage effluent to a jack pine plantation on sand soils resulted in an increase in average nitrate concentration in groundwater of 0.27 ng./1. Phosphorus levels were unchanged. Tree diameter growth increased.

(*h*) **Sediment in a Michigan Trout Stream–Its Source, Movement, and Some Effects on Fish Habitat**, E. A. Hansen, *USDA Forest Serv. Res. Paper NC-59*, 14 p., 1971.

Sediment Movement in a Pool and Riffle Stream, E. A. Hansen, *IASH (Unesco) Publ. 96*, 541-561, 1970.

Estimated Groundwater Yield Following Strip-Cutting in Pine Plantations, D. H. Urie, *Water Resour. Res.* 7, 1497-1510, 1971.

Lake Michigan Snow Squalls Increase Annual Precipitation in the Udell Hills, D. H. Urie, *USDA Forest Serv. Res. Note NC-120*, 4 p., 1971.

Opportunities and Plans for Sewage Renovation on Forest and Wildlands in Michigan, D. H. Urie, *Mich. Acad. IV*, 1, 115-124, 1971.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, NORTHEASTERN FOREST EXPERIMENT STATION, 6816 Market Street, Upper Darby, Pa. 19082. W. T. Doolittle, Director.

310-0242W-810-00

MAINTAINING WATER QUALITY AND INCREASING SUMMER STREAMFLOW IN NEW ENGLAND HARDWOOD ECOSYSTEMS (Durham, N.H.)

(*e*) See WRRC 6, 3.0334.

310-0243W-810-00

PROTECTING WATER QUALITY AND IMPROVING WATER YIELDS FROM FORESTED LAND IN THE CENTRAL APPALACHIANS (Parsons, W.Va.)

(*e*) See Water Resources Research Catalog.

310-0244W-890-00

REDUCTION IN SURFACE-MINING DAMAGES TO FOREST RESOURCES BY IMPROVING MINING PROCEDURES AND REHABILITATION MEASURES (Berea, Ky.)

(*e*) See WRRC 6, 5.0561.

310-0245W-810-00

AMENITIES DERIVED FROM TREES, AND MULTIPLE-USE MANAGEMENT OF MUNICIPAL WATERSHEDS (Pennington, N.J.)

(*e*) See WRRC 6, 3.0422.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION, P. O. Box 3141, Portland, Oreg. 97208. Robert E. Buckman, Director.

311-04757-810-00

WATER YIELD AND EROSION, WENATCHEE, WASHINGTON

(*d*) Field investigations; basic and applied research.

(*e*) Generate information on the relations of moisture disposition and use, and incidence of soil erosion, in forest and range environments to climatic characteristics, vegetative types, soil types, topography, and land uses; and to devise management techniques for ensuring maximum streamflow and minimum erosion and sedimentation in the mid-Columbia River Basin in eastern Oregon and Washington. Studies related to erosion reduction include characteristics of soil related to erodibility; effects of climate, vegetation and parent material on soil development, characteristics of forest humus types; and physical control of erosion by increasing density of vegetation. Factors influencing receipt, disposition, and use of water include head and moisture flux, and partitioning of the solar energy balance over forest canopies; seasonal soil moisture depletion under a lodgepole pine forest; moisture use requirements of six principal conifers; effects of silvicultural treatments, including precommercial thinning and harvest cuttings, on water yields; disposition of intercepted snow and rime ice.

(*g*) A comparison of streamflow records from three small mountain streams in north-central Washington before, during, and after a severe forest fire showed three immediate effects of the fire. Flow rate was greatly reduced while the fire was actively burning, destruction of vegetation in the riparian zone reduced diurnal oscillation of flow rates, and flow rates quickly increased to points above protracted normal depletion rates but to varying degress. No drastic immediate change in stream temperatures was noted.

In an experimental erosion control seeding program after a forest fire, two watersheds were fertilized, one with urea and the other with ammonium sulfate. A third watershed was retained as an unrehabilitated control. For a 60-day period during and following fertilization, 1.37 kilograms of urea-N and 2.90 kilograms of nitrate-N were estimated to have been carried by streamflow from the watershed fertilized with 27.5 metric tons of elemental nitrogen as urea. On the watershed fertilized with 33.16 metric tons of elemental nitrogen as ammonium sulfate, 1.45 kilograms of nitrate-N was estimated to have been transported from the watershed by streamflow.

A spring-actuated maximum temperature indicator was developed for studies of maximum air temperature near

the soil surface. The sensor which employs a temeperature-sensitive wax, is easily read and operates in the range 38-62 °C.

Infiltration and retention of soil water at snowmelt temperature was studied under laboratory conditions. Lowering the water temperature from 25°C to snowmelt temperature decreased soil water conductivity by approximately one-half. At snowmelt temperature, soil water retention volume was 12 percent greater than at 25°C. The results emphasize the importance of temperature as a factor influencing soil water behavior under snowmelt conditions.

(*h*) **Early Effects of Forest Fire on Streamflow Characteristics,** H. W. Berndt, *U.S. Forest Serv. Res. Note PNW-148*, 9 p., 1971.

Monitoring Rime Accumulation by Radioactive Attenuation, W. B. Fowler, *J. Physics E; Sci. Instr.* **3,** 735-736, 1970.

A Spring-Actuated Maximum Temperature Indicator, W. B. Fowler, *J. Range Manage.* **23,** 2, 144-145, 1970.

Measurement of Seasonal Air Temperatures Near the Soil Surfaces, W. B. Fowler, *J. Range Manage.* **24,** 2, 158-160, 1971.

An Approach to the Digital Hygrothermograph, W. B. Fowler, *Bull. Amer. Meteorol. Soc.* **52,** 3, 202, 1971.

Erosion Control Fertilization–From Pot Study to Field Testing, G. O. Klock, J. M. Geist, A. R. Tiedemann, *Sulphur Inst. J.* **7,** 3, 7-11, 1971.

Streamflow Nitrogen Loss Following Forest Erosion Control Fertilization, G. O. Klock, *U.S. Forest Serv. Res. Note PNW-169*, 9 p., 1971.

Snowmelt Temperature Influence on Infiltration and Soil Water Retention, G. O. Klock, *J. Soil and Water Conserv.* **27,** 12-14, 1972.

311-04758-810-00

SOIL STABILITY AND STREAMFLOW

(*b*) Laboratory project with some phases in cooperation with City of Portland, Bureau of Water Works, and Oregon State University.

(*d*) Field investigations; basic and applied research.

(*e*) Determine how logging methods, road construction, and other forest management practices can be improved to curtail erosion, protect fish habitat, maintain water quality, and regulate quantity and timing of runoff. Field research is conducted on experimental watersheds at three field locations in the Cascade Range of western Oregon; Bull Run Watershed (domestic supply area for Portland), H. J. Andrews Experimental Forest, and South Umpqua Experimental Forest. Studies are confined to two forest types representing major segments of the remaining old-growth forest of the Pacific Northwest–Douglas-fir, western hemlock, western redcedar, and Douglas-fir, sugar pine. Precipitation, runoff, erosion, and soil moisture are studied in undisturbed stands and following several methods of logging. Support laboratory facilities are available at the Forestry Sciences Laboratory in Corvallis. Studies are grouped in three categories–to develop basic knowledge of water and nutrient cycling within Douglas-fir ecosystems; to determine how these cycles are affected by commonly used land management practices; and to develop measures to prevent excessive damage resulting from timber harvest and associated activities and to alleviate undesirable effects that do occur.

(*g*) Recent research results from small experimental watersheds show that after complete clearcutting, annual streamflow may increase as much as 18 inches during the years immediately following logging and burning. Minimum streamflow also increased significantly with larger increases following heavier cutting. Extensive logging may increase early winter seasons stormflow but probably does not alter streamflow from major midwinter storms.

Considerable damage from severe winter storms results primarily from soil instability. Surface erosion may be a serious problem in local areas of the Pacific Northwest, but massive soil movements are more common to the region.

When stream surfaces are exposed by logging, maximum stream temperature may increase. The first year after slash was burned on a 237-acre clearcut watershed in the Cascade Range of Oregon, average maximum water temperatures increased 13°, 14°, and 12°F during June, July, and August. A maximum stream temperature of 75°F persisted for 3 hours on a day in July.

Soils on three small experimental watersheds were found to permit rapid rates of water movement as a result of their porous nature. The importance of stone content as a hydrologic factor required some revision of the original soil classification scheme before water storage capacity relationships could be correctly assessed.

(*h*) **Comparative Chemical Water Quality–Natural and Disturbed Streams Following Logging and Slash Burning,** R. L. Fredriksen, *Forest Land Uses and Stream Environment*, Oregon State Univ., p. 125-137, 1971.

Regimes of Streamflow and Their Modification by Logging, J. Rothacher, *Forest Land Uses and Stream Environment*, Oregon State Univ., p. 40-54, 1971.

Principal Mass Movement Processes Influenced by Logging, Roadbuilding, and Fire, D. N. Swanston, *Forest Land Uses and Stream Environment*, Oregon State Univ., p. 29-39, 1971.

The Mechanics of Debris Avalanching in Shallow Till Soils of Southeast Alaska, D. N. Swanston, *USDA Forest Serv. Res. Paper PNW-103*, 17 p., illus., 1970.

Erosion and Sedimentation Following Road Construction and Timber Harvest on Unstable Soils in Three Small Western Oregon Watersheds, R. L. Fredriksen, *USDA Forest Serv. Res. Paper PNW-104*, 15 p., Illus., 1970.

Stabilization of Newly Constructed Road Backslopes by Mulch and Grass-Legume Treatments, C. T. Dyrness, *USDA Forest Serv. Res. Note PNW-123*, 5 p., 1970.

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U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION, P.O. Box 245, 1960 Addison Street, Berkeley, Calif. 94701. H. W. Camp, Director.

312-0246W-810-00

TIMBER AND WATERSHED RESOURCE DEVELOPMENT RESEARCH IN HAWAII

For summary, see Water Resources Research Catalog **6,** 4.0112.

312-04996-810-00

WATER YIELD IMPROVEMENT, CONIFER ZONE

(*b*) Cooperative with U.S. Atomic Energy Commission.

(*c*) Dr. James L. Smith, Project Leader, Water Yield Improvement, Conifer Zone.

(*d*) Experimental; field investigation; basic and applied research.

(*e*) Determine the relationships which exist between the climate and the snowpacks of the Sierra Nevada, and how these relationships are affected by the presence or absence of forest cover, so that the effect of forest cultural practices upon snow metamorphism and melt may be predicted in advance of application of such practices. Present studies emphasize study of snow density changes, water holding capacities, snow metamorphism and melt rates under a variety of meteorological and cover conditions, and the effect of these changes upon timing of delivery of water to streams.

(*g*) Radioisotope studies have estimated the volume of water moving through boles of individual trees. Phosphorous-32 was injected into 60-year old lodgepole pine and red fir by immersing small lateral roots into vials of radioisotope solution. Rates of ascent of water movement in the bole were measured from autoradiographs. The rate and area measurements were then combined into estimates of water flux.

Evapotranspiration could not be determined by measuring soil moisture because snowmelt quickly replenished soil moisture. Estimates of water use suggest coefficients for water balance formulas based on the energy balance approach can be estimated by using data on water movement determined by isotope tracers.

Radioisotope studies have been made of water flow through a limited number of pyroclastic soils typical of much of the juvenile soils of the Sierra Nevada. Water flow through soils having porosities of 44 to 61 percent was traced with tritum and phosphorous-32 isotopes. The rate of flow in saturated zones of the soil ranged from 12.2 to 30.5 cm/hr. The rate depended upon depth to the water table.

A continuing study of the effects of climatic variables, topography and plant cover upon snow hydrology has further emphasized the effect of temperature upon snow hydrology. Snow profiles were collected with the Profiling Snow Gage (described in the 1970 report). The effects of unusual rain-on-snow event in mid-January 1971, which resulted in avalanche warnings in all the western States, was documented with the gage. The build-up of the ice layer upon which slippage occurred was seen with the gage and the conditions under which it might occur again were documented. It is predictable. Further studies have resulted in formulation of a theory of how very light and very heavy density layers occur within snowpacks. These affect hydrology of the packs. Data analyses are currently being performed to test the hypothesis, as well as the effect of cover upon the change.

(*h*) **Development of Some Radioisotopes Procedures for Measuring Water Movement in Trees,** P. W. Owsten, J. L. Smith, H. G. Halverson, *Isotopes and Radiation Technolgy* **7**, 4, pp. 396-401, Oak Ridge, Tenn., 1970.

Further Development of Radioisotope Techniques for Measuring Water Movement in Large Trees, P. W. Owston, J. L. Smith, H. G. Halverson, *TID-25463*, *USAEC*, 38 pp., 1970, available NTIS, Springfield, Va.

The Profiling Radioactive Snow Gage, J. L. Smith, H. G. Halverson, R. A. Jones, *Snow Removal and Ice Control Research*, *Special Rept. 115*, U.S. Army Cold Regions Res. and Engrg. Lab. and Highway Res. Board, Natl. Acad. Sci., pp. 36-45, 1971.

The Profiling Radioactive Snow Gage, J. L. Smith, H. G. Halverson, R. A. Jones, *Trans. Isotopic Snow Gage Information Meeting*, Sun Valley, Idaho, pp. 17-35, 1971, Idaho Nuclear Energy Commission, Idaho Falls, Idaho.

312-04997-810-00

HYDROLOGIC PROCESSES, MOUNTAIN WATERSHEDS

(*c*) Mr. Henry W. Anderson, Work Unit Leader.

(*d*) Experimental and theoretical; basic and applied research.

(*e*) Through analytical modeling to advance the state of knowledge of watershed hydrology and sedimentation, and particularly, knowledge of the relationship of watershed management and other hydrologic processes at the water sources to water yield, floods, sedimentation, and water quality delivered from wildland watersheds.

(*g*) Sources of non-ergodicity in hydrologic data and nonlinearity in hydrologic processes were studied by principal components analysis. Specifically, increases in sediment discharge from 30 watersheds after two major flood-producing storms were analyzed. Relative flood size in a watershed was expressed as the deviation from average annual flood size, divided by the mean annual discharge for each watershed analyzed. Nonlinearity was evaluated by studying the interactions between variables of watershed conditions such as type and amount of roads, past forest fires, and logging, and variables of geologic rock type and topography. Topographic variables were calculated from slopes of 0.5-mile streams, elevation distribution, and surface path lengths. Sediment discharge was calculated from measured suspended sediment concentration, using the flow duration-sediment method. The flow duration was the ::long-term" average annual distribution of streamflow. The flow duration was the same for each year both before and after floods, therefore; the method yielded the expected annual suspended sediment discharge for a specific watershed condition and year. Analysis of 11 years of sediment data after the December 1955 flood and 3 years' data after the December 1964 flood were made by regressing on reduced rank principal components.

Major increases in sediment discharge occurred after each major flood. The first year after the December 1964 flood, sediment discharge increased by as much as 21,000 tons per square mile per year, and the sedimentation was as much as five times the preflood amount–assuming identical streamflow. A major result of the study was the evidence that poor logging practices, such as placing roads adjacent to streams and landings in draws, was associated with greater increases in suspended sediment concentration after the floods. The increases in sediment discharge were greatest on the steepest and higher-elevations watersheds. Watersheds with greatest coefficient in variation of path lengths had least increases; this difference might be interpreted as a lag in sediment delivery. Increases in sediment discharges were generally less each successive year after a flood. Equations were developed to relate the rate of decline of the increases to flood size in a watershed, years since the flood, and watershed condition. The amount and duration of increases in sediment discharge associated with changes brought about by large floods can affect watershed management decisions and programs requiring estimates of long-term sedimentation from watersheds.

(*h*) **Storage and Delivery of Rainfall and Snowmelt Water as Related to Forest Environment,** H. W. Anderson, *Proc. 3rd Microclimate Symp. Seebe*, Alberta, Canada 1969, 51-67, 1970.

Principal Components Analysis of Watershed Variables Affecting Suspended Sediment Discharge After a Major flood, H. W. Anderson, Proc. Int. Symp. on Results of Research in Representative and Experimental Basins, Wellington, New Zealand, Dec. 1970, *Int. Assoc. Sci. Hydrol. Publ. 96*, 405-416, 1970.

Relative Contributions of Sediment from Source Areas and Transport Processes, H. W. Anderson, *Proc. Symp. on Forest Land Use and Stream Environment*, Oregon State Univ., Corvallis, Oct. 1970, pp. 55-63, 1971.

International Symposium on Mathematical Models in Hydrology, Warsaw Poland July 26-31, 1971, H. W. Anderson, *EOS*, *Trans. Amer. Geophys. Union* **53**, 1, 25-26, 1972.

312-04998-810-00

FLOOD AND SEDIMENT REDUCTION IN THE NORTHERN COAST RANGES OF CALIFORNIA

(*b*) Cooperative with California Div. of Forestry and Humboldt State College.

(*c*) Dr. Jay S. Krammes, Project Leader, Flood and Sediment Reduction, Pacific Southwest Forest and Range Expmt. Sta., 1550 B Street, Arcata, Calif.

(*d*) Experimental; field investigations; basic and applied research.

(*e*) Basic studies of forest hydrology which will suggest methods of land management for improving water quality, maintaining fish habitat, preventing floods and controlling sediment in the northern coast ranges of California. The streams of California's northern coast range mountains are notorious for the high sediment loads they carry and for their periodic floods. Mass erosion processes, particularly landslides and soil creep, may account for much of the sediment reaching streams. Because soil creep and landslides are prevalent in the zone, a study of gravitational mass movement will form an effort to develop the means of estimating the consequences of mass movement in terms of sedimentation. The ultimate objective is to develop the means of predicting the role of land management practices, such as logging and road building in initiating or accelerating mass movement.

(*g*) Floods from streams flowing to the Pacific cause an average annual damage of more than $520 per square mile. More than half of the total damage occurs in small watersheds–those with areas of less than 390 square miles. Since almost all the flood waters originate in wildland areas, it is possible that this problem may be moderated by management of small, wildland watersheds. Calibration of streamflow in two small watersheds (about 1200 acres each) of Caspar Creek was completed during 1967 followed by the construction of the main haul logging road in the South Fork watershed. These watersheds are being used to determine the effect of redwood-Douglas-fir logging practices on streamflow and sediment production. In the South Fork study watershed the immediate effects of timber removal for road construction, road building and bridge construction on turbidity, bed load movement and fish habitat did not extend far downstream nor persist for any extended period. The effect was most predominant during the construction period and the first year following construction.

A study of water use by trees in the mixed conifer type was recently completed at the Challenge Experimental Forest in the north central Sierra Nevada. The information gathered is illustrated by the following data for an isolated mature sugar pine. Soil moisture depletion around the tree, calculated from a network of soil moisture access tubes, was limited to a circle with 41-foot radius. Depletion from this plot in 1967 was the equivalent of 3.9 inches (1730 cubic feet) more than from the area immediately surrounding it. The depletion was 4.8 inches (2120 cubic feet) greater in 1968. The tree was felled following the 1968 season, and the 1969 moisture depletion from the 41-foot plot was 1.6 inches *less* than from the surrounding area. Although the outer area was devoid of trees and shrubs, it had a substantial ground cover of poison oak and bracken fern, which presumably accounts for the difference in water use.

(*h*) **Translocation of ^{14}C in Ponderosa Pine Seedlings,** *Canadian J. Bot.* **49,** 167-171.

312-04999-810-00

FLOOD AND SEDIMENT REDUCTION FROM STEEP UNSTABLE BRUSHLAND OF THE SOUTHWEST

(*b*) Cooperative with California Div. of Forestry, Univ. of California, Los Angeles.

(*c*) Dr. Raymond M. Rice, Project Leader, Pacific Southwest Forest and Range Expmt. Sta., 110 North Wabash Ave., Glendora, Calif. 91740.

(*d*) Experimental; field investigations; basic and applied research.

(*e*) To gain an understanding of the runoff and erosion processes of steep, unstable chaparral watersheds and their contribution to downstream floods and sedimentation, and to develop effective land management practices to combat excessive runoff and erosion, both as emergency measures following fires and as a means of establishing long-term environmental stability.

(*g*) A watershed scale pilot test of the use of a wetting agent to reduce post-fire erosion failed to show any treatment effect. Laboratory studies were undertaken to discover why the reduction in erosion found on previous plot tests did not occur. These investigations led to the discovery that surfactants exposed to sunlight on a *wettable* soil surface reached a maximum effectiveness 10 to 15 days after application and declined thereafter, reaching a constant low level in about 30 days. A laboratory study of the influence of plant species on fire induced water repellency indicated that burning conditions were much more important than plant species. Under severe burning conditons grass, which does not produce water repellency under natural fires, produced the most severe repellency of species tested. Field trials of the use of wetting agents in irrigation water applied to a recent burn showed that the chemical gave seeded grasses a competitive advantage over competing forms.

An empiric test was conducted of the ability to predict landslide occurrences from analysis of physiographic features on aerial photos. The study area was underlain by marine sedimentary geologic formations and had burned in a brush fire 5 years prior to the landslide producing storm in 1969. Eighty percent of the landslides occurring in 1969 occurred on areas which were typed as being unstable using photographs taken in 1968.

(*h*) **Water Repellent Soils: A Worldwide Concern in Management of Soil and Vegetation,** L. F. DeBano, *Agr. Sci. Rev.* **7,** 2, 11-18, 1969.

The Effect of Hydrophobic Substances on Water Movement in Soil During Infiltration, L. F. DeBano, *Soil Sci. Amer. Proc.* **35,** 2, 340-343, 1971.

Translocation of Hydrophobic Substances into Soil by Burning Organic Litter, L. F. DeBano, L. D. Mann, D. A. Hamilton, *Soil Sci. Soc. Amer. Proc.* **34,** 1, 130-133, illus., 1970.

Factor Analysis for the Interpretation of Basin Physiography, R. M. Rice, *Intl. Hydrol. Symp. Proc.*, Wellington, N.Z., 1970, 253-268.

Effect of High Intensity Storms on Soil Slippage on Mountainous Watersheds in Southern California, R. M. Rice, G. T. Foggin III, 1971, *Water Resour. Res.* **7,** 6, 1485-1496.

Wetting Agent Fails to Curb Erosion from Burned Watershed, R. M. Rice, J. F. Osborn, *USDA Forest Serv. Res. Note PSW-219*, Pacific SW Forest & Range Expmt. Sta., Berkeley, Calif., 5 p., illus. 1970.

312-07000-810-00

WATERSHED SYSTEMS DEVELOPMENT UNIT

(*b*) Division of Watershed Management, U.S. Forest Service, National Forest System.

(*c*) James E. Reid, Project Leader, Watershed Systems Development Unit.

(*d*) Theoretical; developmental, basic and applied research.

(*e*) Development of a systems approach to the resource management of National Forest land; and the development of analysis tools through the use of computers to solve day-to-day, on the ground problems in watershed and natural resource management.

Provide consulting, training, and computer analysis services to the water and land managers of the National Forest System. Resource analysis tools are developed, and watershed management research results are blended with the water and related resource problems of the land manager.

(*g*) Since the formation of this work unit in 1966, about 60 computer programs are operational, or nearly so, to reduce streamflow, precipitation, temeperature, wind movement, etc., data and to analyze hydrometeorological data for determining water balances, erosion and sedimentation amounts, etc. These programs have been designed for and are particularly useful to water resource managers in the National Forest System. The unit recently

completed an operational version of an analytical system called the Resource Capability System. The purpose of this system is to assist decision makers in evaluating alternative uses of forest and related lands. A user's guide has been partially completed which outlines a systems approach to resource management. Operations research tool such as linear programming, simulation techniques for the analysis of hydrologic information and the necessary supporting programs are currently operational.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION, 240 W. Prospect Street, Fort Collins, Colo. 80521. Raymond Price, Director.

313-0074W-810-00

WATERSHED MANAGEMENT RESEARCH (CHAPARRAL), TEMPE, ARIZONA (formerly 657A).

For summary, see Water Resources Research Catalaog.

(*h*) **A Computer Program for Computing Streamflow Volumes,** P. A. Ingebo, W. B. Casner, G. L. Godsey, *USDA Forest Serv. Res. Note RM-203*, p. 1-8, 1971.
Reducing Excess Readouts from Digital Streamflow Recorders, A. R. Hibbert, W. B. Casner, *Water Resour. Res.* **7,** 2, 415-418, 1971.
Suppression of Channel-Side Chaparral Cover Increases Streamflow, P. A. Ingebo, *J. Soil Water Conser.* **26,** 2, 79-81, 1971.

313-02658-810-00

WATER YIELD IMPROVEMENT IN THE BLACK HILLS

(*d*) Experimental; basic and applied research.
(*e*) Determine geologic, geomorphic, and forest factors that influence or relate to quantity and timing of the water yield.
(*h*) **Throughfall and Stemflow Relationships in Second-Growth Ponderosa Pine in the Black Hills,** H. K. Orr, *USDA Forest Serv. Res. Note RM-210*, 1972.

313-03569-810-00

WATERSHED MANAGEMENT RESEARCH, LARAMIE, WYOMING

(*b*) Laboratory project and Bureau of Land Management.
(*d*) Field investigation; applied research.
(*e*) Water yield characteristics of big-sagebrush lands are being studied on plots and gaged watersheds, and hydrologic effects of control measures are being determined. Methods for increasing snow accumulation in windswept areas are also being developed and tested.
(*h*) **Design of a Watershed Snow Fence System, and First-Year Snow Accumulation,** R. D. Tabler, *Proc. 39th Western Snow Conference*, Apr. 1971, Billings, Mont., p. 50-55.
A Recording Gage for Blowing Snow, R. D. Tabler, R. L. Jairell, *USDA Forest Serv. Res. Note RM-193, 7 p., 1971.*

313-03895-810-00

WATER YIELD IMPROVEMENT IN ALPINE AREAS AND AVALANCHE PREDICTION AND PREVENTION

(*d*) Experimental and field investigation; applied research.
(*e*) Determine methods for controlling the deposition of snow in alpine areas in order to increase summer streamflow from late-lying snowfields. To reduce danger from snow avalanche to winter sports areas, highways, mining operation, and homes by improving the evaluation and forecasting of avalanche hazard and developing methods of stabilizing the snow cover on mountain slopes.
(*h*) **Calibrating the Snow Particle Counter for Particle Size and Speed,** R. A. Schmidt, Jr., E. W. Holub, *USDA Forest Serv. Res. Note RM-189*, 8 p., illus., 1971.
Processing Size, Frequency, and Speed Data from Snow Particle Counters, R. A. Schmidt, Jr., *USDA Forest Serv. Res. Note RM-196*, 4 p., illus., 1971.
An Infrared De-Icing Unit for Cup Anemometers, A. Judson, *USDA Forest Serv. Res. Note RM-187*, 4 p., illus., 1971.

313-08437-810-00

WATER YIELD IMPROVEMENT FROM SUBALPINE FOREST AND RANGE LANDS

(*d*) Experimental and field study.
(*e*) Study the hydrology of subalpine areas and to design and test practices to improve timing and amount of streamflow.
(*h*) **A Model for Updating Streamflow Forecasts Based on Areal Snow Cover and a Precipitation Index,** C. F. Leaf, A. D. Haeffner, *West. Snow Conf., Proc.* **39,** 9-16, Billings, Mont., April 1971.
Guidelines for Sampling Area-Mean Water Equivalent in Forested Watersheds, C. F. Leaf, J. L. Kovner, in *Hydrometeorological Networks in Wyoming–Their design and Use*, Hydrol. Seminar, (Laramie, Wyo., May 1971) Proc. p. 159-167, *Water Resour. Res. Inst. Rep.*, Wyo. Univ., Laramie.
An Inexpensive Heated Thermistor Anemometer, J. D. Bergen, *Agr. Meteorol.* **8,** 395-405, 1971.
Sediment Yields from Central Colorado Snow Zone, C. F. Leaf, *J. Hydraul. Div., ASCE Proc.* **97,** HY2, 350-351, Closure.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, SOUTHEASTERN FOREST EXPERIMENT STATION, P.O. Box 2570, Asheville, N.C. 28802. Stephen G. Boyce, Director.

314-0247W-810-00

IMPROVEMENT OF QUANTITY, QUALITY AND TIMING OF WATER YIELDS IN THE SOUTHERN APPALACHIANS-PIEDMONT

For summary, see Water Resources Research Catalog **6,** 3.0377.

314-0248W-810-00

HYDROLOGY AND MANAGEMENT OF WETLAND FORESTS

For summary, see Water Resources Research Catalog **6,** 2.1267.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, SOUTHERN FOREST EXPERIMENT STATION, T-10210 Federal Building, 701 Loyola Avenue, New Orleans, La. 70113. R. L. Youngs, Director.

315-06973-810-00

IMPROVEMENT IN TIMING OF WATER YIELD ON FOREST WATERSHEDS IN THE OZARK-OUACHITA HIGHLANDS

(*d*) Field investigations; applied research.
(*e*) Formulate watershed management practices for prolonging summer flow of streams in the Ozark-Ouachita Highlands. Research is concentrated on identifying hydrologic characteristics of soils showing greatest potential for receiving and storing water to augment streamflow during summer; determining locations and extent of such soils; and assessing responses of these sites to methods of vegetation manipulation designed to stabilize streamflow. Runoff and

sediment are measured on three small watersheds in the Ouachita Mountains and on six in the Ozark Mountains. Groundwater is monitored by neutron probe on watersheds in both mountain areas. Calibration has been achieved on the Ouachita watersheds, and changes in forest vegetation were imposed on two units during 1969. Calibration is continuing on Ozark watersheds, with two scheduled for treatment of overstory in 1970. Related studies of soil water receipt and disposal are conducted on plots.

(*g*) Results to date have been mainly in the development and improvement of techniques and equipment to determine water yield and quality on experimental watersheds and to determine preliminary hydrologic responses to manipulation of forest vegetation.

(*h*) **Thinning Increases Throughfall in Loblolly Pine Plantings,** T. L. Rogerson, *J. Soil and Water Conserv.* **23,** 141-142, 1968.

Half-Minute Counts for Neutron Probes, T. L. Rogerson, *Soil Sci.* **110,** 359-360, 1970.

Hydrologic Characteristics of Small Headwater Catchments in the Ouachita Mountains, *USDA Forest Serv. Res. Note SO-117*, 5 pp., 1971.

315-06974-810-00

DEVELOPMENT OF REHABILITATION AND MANAGEMENT TECHNIQUES FOR FOREST WATERSHEDS ON ERODED OR HIGHLY EROSIVE SITES IN THE COASTAL PLAIN AND PIEDMONT REGIONS

(*b*) Cooperative with Soil Conservation Service and the University of Mississippi.

(*d*) Field investigations; basic and applied research.

(*e*) Develop methods for establishing vegetation to retard runoff and erosion on depleted forest sites, and to formulate methods for minimizing runoff and erosion on rehabilitated forest sites as a result of cultural treatments, harvesting, and regeneration. Information is acquired concerning factors that limit establishment, growth, and maintenance of protective cover on forest land. Limitations investigated include adaptability of native and exotic species to deteriorated sites, protective values of such plants, and means whereby eroded soils can be ameliorated to favor establishment and growth of cover. Rehabilitation studies are conducted on sites ranging from friable sands and loess deposits of the upper Coastal Plain to exposed clay subsoils representative of Piedmont sites. Investigations are conducted to assess effects on runoff and erosion of forest thinning intensities and schedules, harvest cuts, site preparation, regeneration techniques, prescribed burning, control of cull hardwoods, and logging methods.

(*g*) Study has shown that loblolly pines retard runoff and eliminated accelerated erosion after canopies are closed, but from establishment to crown closure litter accumulation is insuffficient for optimum protection. Fertilization of pines has increased needle production and thereby accelerated litter accumulation, but supplemental vegetation is needed to stabilize many sites, pending establishment of pine litter cover. Among numerous herbs evaluated, several introduced grasses have proven suitable for supplementing pine plantations. On very severe sites, organic mulches have materially reduced erosion during two years following pine establishment.

(*h*) **Fertilizers for Bullet-Planted Loblolly Pines,** P. D. Duffy, *Miss. Farm Res.* **33,** 7, 1, 5, 1970.

Site Rehabilitation Under Planted Redcedar and Pine, D. C. McClurkin, in *Tree Growth and Forest Soils*, pp. 339-345, Proc. 3rd N. Am. Forest Soils Conf., N.C. State Univ., 1970.

Texas 'Lost Pines' Not Superior on Dry Sites in Northern Mississippi, B. P. Dickerson, *USDA Forest Serv. Res. Note SO-119*, 4 pp., 1971.

Loblolly Pine Seedlings Respond to Foliar Nitrogen Application, P. D. Duffy, *USDA Forest Serv. Res. Note SO-122*, 4 pp., 1971.

Containerized Pines for Eroded Watersheds, D. C. McClurkin, *J. Soil and Water Conserv.* **26,** 1, 25-26, 1971.

Systems for Measuring and Computing Ephemeral Runoff from Small Watersheds, P. D. Duffy, T. R. Dell, *USDA Forest Serv. Res. Note SO-138*, 4 pp., 1972.

315-06975-820-00

IMPROVEMENT OF GROUNDWATER SUPPLIES IN THE SOUTHERN COASTAL PLAIN

(*d*) Field investigation; applied research.

(*e*) Develop cover conditions and land-use methods on forest areas to regulate volume, quality, and distribution of surface water; and to augment groundwater supplies in important recharge areas and on watersheds. Investigations are designed to facilitate identification of geologic conditions and outcrop areas where management of cover to augment aquifer recharge is most feasible; development of techniques for assessment of water storage and transmission capacities of important outcrops; evaluation of forest conditions affecting water entry into the soil and the quantity available for deep recharge; and development of forest management methods that favor increase of groundwater.

(*g*) Study has demonstrated that pine plantations on eroded Coastal Plain sites are reducing sedimentation and at the same time effectively restoring the ability of permeable outcrops to accept and store rainfall. On grass-covered watershed with predominantly well-drained soils, prescribed burning increased stormflows, overland flows, peak discharges, and sediment production for at least three years. Identical treatment on a catchment having soil with a shallow fragipan increased overland flows, peak flows, and sediment yield but did not influence storm-flow volumes. A computer program has been developed for converting neutron probe readings to soil water equivalents, and source decks and detailed instructions have been made available.

(*h*) **Hydrologic Effects of Prescribed Burning and Deadening Upland Hardwoods in Northern Mississippi,** S. J. Ursic, *USDA Forest Serv. Res. Paper SO-54*, 15 pp., 1970.

DEPARTMENT OF THE AIR FORCE, AEROSPACE RESEARCH LABORATORIES, APPLIED MATHEMATICS RESEARCH LABORATORY, Wright-Patterson Air Force Base, Ohio 45433. Dr. D. A. Lee, Director.

316-08438-020-00

NUMERICAL STUDIES OF TURBULENT CHANNEL FLOW

(*c*) Dr. Jon Lee.

(*d*) Basic research.

(*e*) Investigate the feasibility of simulating turbulent channel flows numerically on a computer based on the Navier-Stokes equations. There are two basic questions. Can we represent the evolution of many flow systems in a statistical sense by a typical flow system in the ensemble? Do the Navier-Stokes equations under the channel flow configuration exhibit a steady-state flow behavior?

(*g*) To get a feel of the problem, we have investigated the Burgers turbulence models for a channel flow which share certain nonlinear dynamics with the Navier-Stokes equations. For the simple models, the two questions have been answered in detail. That is, the Burgers turbulence models have a stationary flow state that can be attained from the arbitrary flow conditions. Work is being done with the actual channel flow described by the full Navier-Stokes equations.

(*h*) **Burgers Turbulence Model for a Channel Flow,** J. Lee, *J. Fluid Mech.* **47,** 321-335, 1971.

Burgers Turbulence Model with Two Velocity Components, J. Lee, *Phys. Fluids* **15,** 540-545, 1972.

DEPARTMENT OF THE ARMY, COASTAL ENGINEERING RESEARCH CENTER, Kingman Building, Fort Belvoir,

Va. 22060. James L. Trayers, Colonel, CE, Commander and Director.

317-02193-490-00

DEVELOPMENT OF DESIGN CRITERIA

(*g*) Shore Protection Manual. This was previously reported as TR No. 4. The Shore Protection Manual (SPM) will replace CERC Technical Report No. 4 entitled, "Shore Protection, Planning and Design." It will contain 7 chapters and 4 appendices.
Coastal Engineering Manual. A Coastal Engineering Manual is to be prepared to eventually supersede the forthcoming SPM. The purpose of this manual is to provide the practicing engineer with a comprehensive publication encompassing all facets of coastal engineering. The format of the manual will comprise 6 chapters which will summarize the information included in detail in 24 appendices.
Steel Corrosion Protection. Periodic measurements are being taken to determine the rate of corrosion of both "mariner" and ordinary steel in the bents supporting the CERC Prototype Experimental Groin at Pt. Mugu, California. Corrosion measurements have been taken from four main corrosion resistant steel support piles. These piles were removed from the structure thus allowing a detailed examination of full length of the piles. In addition to these measurements, plans have been initiated to study the effects of corrosion on the prestressing steel in selected prestressed concrete planks recently installed in that groin.

317-02195-430-00

COASTAL WORKS EVALUATION

(*d*) Field investigation; applied research.
(*e*) Data are collected before, during, and after construction of shore structures including repetitive surveys, material sampling, littoral forces (to extent possible) and that relating to techniques and materials of construction. The data are machine processed, collated and studied. The purpose is to procure and develop data on all types of shore improvement structures and methods, to be used to determine their effectiveness and to develop new criteria or changes in existing criteria applicable to functional and structural design of future structures.
(*g*) Data collection and processing were continued at the following locations: Hampton Beach, N.H.–beach fill and nourishment; Wallis Sands Beach, N.H.–beach fill and terminal groin; Suffolk County, L.I., N.Y.–groins; Chesapeake Bay Bridge Tunnel, Va. (terminal islands)–rock revetments; Carolina Beach Inlet, N.C.–experimental dredging of throat of unimproved inlet; Carolina Beach, N.C.–beach fill, dunes and nourishment; Wrightsville Beach and Masonboro Inlet, N.C.–beach fill, dunes and nourishment from littoral reservoir at experimental weir-type jetty; Hunting Island, S.C.–beach fill and nourishment; Texas Gulf Coast–beach change and inlet monitoring; California Cooperative Studies–project surveillance and basic data collection funded on matching basis with State of California; Hawaii Basic Studies–project surveillance and basic littoral drift studies for Hawaii coast; Ponce de Leon Inlet, Fla.–weir-jetty and littoral retention basin under construction; Virginia, Biscayne Key, and Treasure Island, Fla.–recently completed beach fill projects; Lake Michigan Littoral Drift Study.
Data collection on behavior of beach and underwater bottom slopes at updrift, and downdrift of groin structure was continued through 1971 until November 1971, at which time the panel system in the experimental groin was removed. Compilation and analysis of collected data were initiated.

317-06994-400-00

INLET AND ESTUARY DYNAMICS

(*c*) R. P. Savage, Asst. Chief, Research Division.
(*d*) Theoretical and experimental, development.
(*e*) This project consists of research and development on inlet and estuary dynamics including theoretical, laboratory, and field studies of the tidal hydraulics, shoaling, bank erosion, pollution and flushing, and the interaction of ocean, inlet and estuary factors. It also includes the functional design of structures to stabilize or modify various factors of the ocean-inlet-estuary system. Research will provide an improved understanding of inlet and estuarine dynamics, in particular tidal hydraulic phenomena, shoaling, bank erosion, pollution and flushing and effects of and to adjacent shores.
(*g*) The office study of inlets along U.S. coastlines continued. Fifty-one inlets were measured, with forty-five categorized as inlets in long alluvial barriers. Evaluation of measurements from previous years prompted a redefinition of variables and all were measured during 1971, using the revised definitions. Programs were written and adapted to compile histograms and to prepare scatter plots of inlet variables. A preliminary evaluation of the resulting data indicated accuracies sufficient to support reconnaisance-type studies. From a further evaluation of these data it was concluded that the minimum inlet width is directly related to the cross-sectional area; a logarithmic relationship exists between the width and the offset; and the width to depth ratio is quite high. The classification of inlets study continued with emphasis on the relation between longshore sediment transport and inlet offset. Overlapping offset appeared to occur when there was an adequate and dominantly one-directional supply of drift and longshore transport. This conclusion agreed with visual observations of wave direction and height along the south shore of Long Island, New York.
Study of the Mechanics of Flow in Inlets continued with attention to the hypothesis that flow over a sandy bed will increase the velocity until the current exceeds the velocity at which ripples are the stable bed form. For flow in an equilibrium sandy channel, the maximum attainable velocity is usually from 5 to 6 ft/sec, whether the flow is a stream, a laboratory flume, a longshore current, or a tidal current. When the flow exceeds this velocity, the entire bed goes into motion, the cross-sectional area increases, the velocity then drops to a value at which ripples are stable. Thus, according to this hypothesis, the stable cross-sectional area of an inlet through a sandy channel is determined by the maximum tidal prism which can fit through the inlet and not exceed the ripple-forming regime on the bed. (Note, that in this hypothesis, it is not the velocity when sediment motion is first initiated, but the velocity when ripples are wiped out that controls the cross-sectional area.) It is expected that the occurrence of the maximum tidal prism may be infrequent, so that inlets may not always show this relation during normal tidal cycles. Work is underway to better test this hypothesis using recognized principles of fluid mechanics along with empirical relations from O'Brien and from river studies.

317-06995-880-00

COASTAL ECOLOGY STUDIES

(*d*) Field investigation, applied research.
(*e*) Five "ecological problem areas" relating to engineering activities are being investigated; offshore construction, offshore dredging, coastal waste disposal, estuarine dredging, and hurricane and ocean storm protection structures and activities. For each "ecological problem area," a planning document will be prepared and will include a highly selective annotated bibliography, the expected ecological consequences, the current state of knowledge of

ecolgical effects, and additional research necessary to provide knowledge of ecological effects where that knowledge is missing. In advance of completion of these planning studies, several field studies have been initiated as follows: 1. Offshore Dredging: An ecological monitoring study of a beach erosion control project utilizing an offshore borrow area for the source of sand 2. Coastal Waste Disposal: A large-scale study of the ecological effects of waste disposal in the New York Bight (funded from other sources) is being supervised. An intensive study on the development of techniques for more sophisticated analyses of trace (metal) elements in waste materials, and determination of concentrations of these elements in wastes both from treatment plants and in the New York Bight. 3. Estuarine Dredging: A pilot on the stabilization and productive use of dredge spoil utilizing marsh grass.

(*g*) Three field studies monitoring the ecological effects of beach nourishment utilizing offshore dredging were initiated and continued through the year. One was completed and the final report is in work. Planning was initiated for studies on the ecology of live species of clams (one Atlantic, one Pacific), likely to be affected by dredging. The first two years of study on the stabilization and productive use of dredge spoil (establishment of salt marsh using marsh grass) was completed. This study documented the feasibility of this type of activity, developed techniques, and indicated that marsh grass has a long transplanting season, can be transported a considerable distance and be successfully transplanted, and can be established by direct machine planting of seed.

317-08618-420-00

WIND WAVE ACTION IN COASTAL WATERS

(*g*) Ocean Wave Statistics. Continuous analog wave records were made at 3 gages affected by hurricanes. Analysis of those records shows that the cumulative Rayleigh distribution function provides a good fit to the wave height data except for the highest waves. Ratios of the average of the one-third highest waves to the standard deviation of the digital record ranged from 3.95 to 4.93 compared to the accepted value of 4.0. Analysis of 16 records from 4 gages affected by extra-tropical storms also confirmed the suitability of the Rayleigh distribution for wave heights. The log-normal distribution was found to permit a reasonable approximation to the distribution of individual wave periods in a record. See Project No. 6696 in past issues.

Riprap Stability. Tests were conducted with wave periods of 2.8, 4.2, 5.7 and 11.3 seconds. Report in preparation. See Project No. 6486 in past issues.

Determination of Wave Direction. Two proposed mathematical models for determining wave direction from an array of wave gages were tested at CERC, using data from the Pt. Mugu array. Some, but not all of the results appear reasonable. A very careful reanalysis of a numerical algorithm used in these tests and most other efforts to determine wave direction from an array indicates that the system cannot be made fully deterministic without using assumptions that are not fully valid. An examination of many aerial photographs indicates that in the coastal regions waves travel in several narrow direction bands, and that any appearance of radiation arriving from a wide direction band is due mostly to refraction or diffraction.

Wave Runup on Vertical Cylinder. Further testing was conducted in which wave heights were measured by a gage mounted on a vertical cylinder in intermediate water depth, as a periodic laboratory wave passed. The measured wave height was found to be strongly dependent on the orientation of the cylinder relative to propagation direction of the wave, and this dependence was investigated extensively, using as the gage-mount structure a right circular cylinder or one of several H-beams of different horizontal cross-sectional aspect ratios. In 17 of 18 tests in the 96' tank with a wave of steepness greater than 0.01 and with the gage mounted on a circular cylinder or within a channel of an H-beam, the pattern of measured wave height vs. cylinder orientation indicated wave direction to within ± 3°. The difference between wave height measured at a cylinder with a certain orientation and far away from the cylinder resulted primarily from a change in wave crest dimension, caused by flow of the wave crest around the cylinder and runup of the crest onto the cylinder. Tests were also conducted in the CERC Shore Processes Test Basin in which two waves, of different periods and amplitudes and propagating at right angles in intermediate water depths, were incident on a gage mounted within a channel of an H-beam. The pattern of measured peak wave height vs. cylinder orientation indicated roughly the direction of net energy transport. Phenomena observed in this testing program supported the feasibility of using wave height measurements around a suitable cylinder to determine wave direction in the field. A finned-cylinder was designed and constructed, and a testing program initiated to evaluate its suitability for use in the field.

New Bern Stone. Test results were further analyzed and a final report is in preparation. It was concluded that the use of New Bern stone in cover or underlayers of coastal structures in an ocean climate is inadvisable. "Lessons learned" in testing the New Bern stone are expected to enhance future testing of other stones. See Project No. 5837 in past issues.

Development, Fabrication and Test of a Laser Velocimeter System. This project was initiated to implement plans for construction at CERC of a laser velocimeter system, designed primarily for investigation of the turbulent, reversing velocity field within gravity waves. The plans call for use of an Argon-ion laser and three Bragg acousto-optic cells as a light source, together with a photomultiplier tube as a detector of light backscattered from commercially available 0.2 μm-diameter spherical scatterers, introduced into the flow in a low concentration. This system is designed to measure the local velocity vector of magnitude between 0.1 and 3.0 m/s, with turbulent fluctuations of 1 percent or greater intensity.

(*h*) **On the Generation of Long Waves,** *J. Geophys. Res.* **76,** 36, Dec. 1971.

Design of a Three-Dimensional Laser Doppler Velocimeter, in preparation.

317-08619-410-00

SHORE PROCESSES

(*g*) Beach Evaluation Program. For the first time, wave data were collected throughout the year. A total of 4,284 visual wave observations at 27 locations along the East Coast, Gulf Coast and Lake Michigan were collected by volunteer observers. Quarterly statistical tables of the results are available. During the 1971 calendar year the Beach Evaluation Program received 4,141 beach profile surveys completed by Corps personnel. Contributing localities include 151 profiles along the east coast, between Wellfleet (Cape Cod), Massachusetts, and Holden Beach (Cape Fear), North Carolina. These data have been transferred to punched cards, and are currently being edited, prior to final computer processing. During calendar year 1971, 703 pipe profile surveys were made at each of 11 localities between Wellfleet (Cape Cod), Mass., and Holden Beach (Cape Fear), N.C. As part of a general research program investigating wave and tide influence on beach morphology, nine profiles extending from the coast 100,000 feet seaward at each of 50 East and Gulf Coast localities were acquired to mathematically characterize beach profiles, to develop and test criteria for discriminating among groups of profiles, and to define the seaward limit of wave-modified beach profiles. Preliminary results indicate that

profiles across the selected inner continental shelves are divisible into two regions. The inshore zone is characterized by a concave-up profile represented by an exponential curve, and the offshore profile is described mathematically by the equation of a straight line. Coefficients correlating the actual offshore shape with the derived equation of a straight line averaged 0.95 for the 50 profiles. The median slope of the inshore region varies from two to ten times that of the offshore slope. See Project No. 4762 in past issues.

Suspended Sediment. A review was undertaken to determine the present state of knowledge concerning (a) the mechanics of suspension of sediment by wave action, (b) typical suspended sediment concentrations in the surf zone, and (c) experimental techniques for the measurement of suspended sediment concentration in the surf zone. Eight related laboratory and three field studies were reviewed. Laboratory tests were a result of the review of the analytical approaches for prediction of suspended sediment concentration under waves. The purpose is to measure simultaneously the suspended load and bed load transport and subsequently to measure suspended load and the velocity field with a stabilized rippled bed under laboratory wave conditions. It should provide a better understanding of the mechanisms of the two modes of transport. This is necessary for improved quantitative prediction of longshore transport rates. The performance of a 1/4" nozzle pump-type sampler suitable for field use will be evaluated in comparison with an optical concentration meter. The scatter-plot program used to analyze the suspended sediment data collected at Ventnor, N.J. in 1965 was modified to generate scatter plot results of suspended sediment concentration versus related wave parameters for each sampling station. The scatter plots of the modified program yield a more meaningful trend than previous scatter plots which were independent of the sampling stations.

The evaluation of a laser velocimeter system for application in gravity wave measuements proceeded by means of a survey of the technical literature and direct contacts with active researchers in the field. It is now considered feasible to measure the turbulent reversing velocity at a point within a gravity wavetrain with a well-designed velocimeter system. Critical design considerations have been identified to be the size of the probed volume, the number and size of the light-scatterers present, and the laser frequency; design choices have been examined bearing in mind the effect of turbulence in the velocity field on the detected light signal. The acousto-optic modulation system and the detected signal processing system required for a suitable laser velocimeter system are not standard commercially available items. See Project No. 2660 in past issues.

Instrument Development. A blade position indicator for the wave generator of the large wave tank was designed and fabricated. This indicator will provide essential information for many of the tests conducted in the large wave tank at CERC. A four-channel instrument package for measuring water currents while mounted on a moving underwater vehicle was developed and used successfully on an underwater sled during a Radioactive Isotope Sample Test at Pt. Mugu, California during October 1971. In conjunction with the underwater current meter unit, a battery eliminator and charger was designed and fabricated to permit bench operation from 115 volt AC power and to provide for optimum battery use. Development of an underwater pressure transducer and modulation unit to be used with a data transmitting buoy for wave measurements is nearing completion. This is a portable instrument for short wave measurements. Testing of the completed system is scheduled to begin in early 1972.

(*h*) **A Review of Longshore Sediment Transport Data,** presented at *52nd Ann. Mtg., Amer. Geophys. Union*, Washington, D.C., 1971.
Visual Observation of Nearshore Wave Direction, presented at *52nd Ann. Mtg., Amer. Geophys. Union*, Washington, D.C., 1971.
Beach Changes Caused by a Northeaster Along the Atlantic Coast, presented at *Ann. Mtg., Geol. Soc. Amer.*, 1971.
The CERC Beach Evaluation Program, Abstract, *2nd Natl. Coastal and Shallow Water Res. Conference.*
Suspended Sediment Concentration in the Surf Zone, presented at *52nd Ann. Mtg., Amer. Geophys. Union*, Washington, D.C., 1971.

317-08620-420-00

LONG PERIOD WAVES AND SURGES

(*g*) The grid system was established for the two-dimensional mathematical model of long wave propagation in Pamlico Sound. A one-dimensional numerical solution for the "enclosed basin surge problem" was developed and this method was included in proposed new "Shore Protection Manual" scheduled for publication by CERC in the near future. Further investigations are underway and the results will be the subject of a future technical paper.

317-08621-470-00

HILO HARBOR SURGE

(*e*) To analyze wave records collected by the University of Hawaii and any other available data to obtain a better understanding of the cause of the periodic motion of ships moored in Hilo Harbor.

(*g*) Edit programs were established for salvaging limited, but potentially useful, data from a large volume of data collected during earlier years.

317-08622-410-00

ENVIRONMENTAL DATA COLLECTION

(*g*) Radioisotopic Sand Tracer. Field testing of radioactive tracers (gold tagged sand) was accomplished at Masonboro Inlet, North Carolina, and at Point Mugu, California. The test at Masonboro Inlet, N.C. was conducted during March 1971 to determine littoral movement in the vicinity of the weir jetty and in the inlet. A field test was conducted at the Prototype Experimental Groin (Pt. Mugu, Calif.) during September-October 1971. Continuous time and plug injections were made to test recently derived longshore transport models. In addition, a lone source was placed 600' north of the groin to trace sediment movement to and around the groin structure. Analysis of this data is underway. An instrumented sled for current measurements and a bottom elevation monitor (utilizing a fixed Cesium-137 source and collimated scintillation detector) were designed and successfully tested during the test at Pt. Mugu. Fabrication of a simplified data acquisition system has been completed at the Oak Ridge National Laboratories. See Project No. 3897 in past issues.

Ocean Wave Climatology. The computer program for the digital analysis of East Coast wave records was optimized for operational use. The program edits the data and computes the spectrum. Errors are removed by averaging between good values when the separation does not exceed 1.25 sec. Spectra were computed from four daily recordings for all the active East Coast wave gages from 31 August 1971 through the end of the year. Acceptable results were stored on digital magnetic tapes. Spectra for one of the Pt. Mugu wave gages were computed from April '70 through March '71. The characteristic spectrum shape at Pt. Mugu demonstrated a long period peak with maximum energy density at periods longer than 9 seconds and a shorter period peak, usually less than 7 seconds. Usually the energy density decreased to near zero values between the two peaks. Spectra of the horizontal velocity

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about two feet above the bottom were computed for 25-30 June 1970. The wave records from the Cape Fear Light Ship for the years 1967, 1968 and 1969 were examined in an effort to determine a wave climatology for Holden Beach, N.C.

Review of wave data analysis indicated that the spectrum-density analysis is suitable for most purposes. Several tests were conducted to determine the effect of changing the duration of the digital magnetic tape records on spectral results. Analyses based on records of 1,024 seconds in duration indicated a greater stability than those based on records of 512 seconds in duration. Little was gained by extending the duration to 2,048 seconds; thus, 1,024 seconds duration with a recording rate of four samples per second, was adopted as the standard for field data. The effect of several windows on smoothing procedures was investigated. For general CERC use it was concluded that the Cosine Bell data window, equivalent to hanning was suitable. Wave height distribution functions facilitated the comparison of wave height climates at different locations. It was determined that both the modified exponential distribution function and the log-normal distribution function fit the observed significant wave height data.

Sand Inventory Studies. Study and analysis of data collected in the Florida Inner Continental Shelf (ICONS) Sand Inventory Program continues; a report for the Cape Kennedy area is in review and data reduction and report writing is in progress for the North Florida region from Cape Kennedy to the Florida-Georgia state line. The ICONS report for the area between Palm Beach and Cape Kennedy was published in February 1971 as TM 34. Work on the New York Bight ICONS study is continuing; data analysis is nearly complete. ICONS reports for Cape Cod Bay, Mass. and Saco Bay, Maine were initiated in June and September, respectively; data analysis is continuing for both regions. See Project No. 4763 in past issues.

DEPARTMENT OF THE ARMY, U.S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY, P.O. Box 282, Hanover, N.H. 03755. Director.

318-0249W-810-00

PHYSICS AND CHEMISTRY OF SOIL, WATER AND INTERFACIAL PHENOMENA

For summary, see Water Resources Research Catalog **6**, 2.1026.

318-0250W-810-00

SNOW AND ICE COVER INVESTIGATIONS

For summary, see Water Resources Research Catalog **6**, **2.1027.**

318-0251W-810-00

COLD REGIONS HYDROLOGY

For summary, see Water Resources Research Catalog **6**, 2.1031.

318-0252W-300-00

COMPUTER MODELS OF TWO-DIMENSIONAL RIVER TEMPERATURE FIELDS OPERATED BY ARTIFICIAL HEAT SOURCES

For summary, see Water Resources Research Catalog **6**, 2.1032.

318-0254W-820-00

GROUNDWATER PREDICTION STUDIES

For summary, see Water Resources Research Catalog **6**, 2.1037.

318-0255W-810-00

HYDROLOGIC STUDY OF SMALL ALASKAN WATERSHED

For summary, see Water Resources Research Catalog **6**, 2.1042.

318-0256W-810-00

A BIOCLIMATIC ASSESSMENT OF STREAM RUNOFF, FLOOD OCCURRENCE AND SLOPE INSTABILITY IN INTERIOR ALASKA

For summary, see Water Resources Research Catalog **6**, 4.0193.

318-0257W-390-00

ENGINEERING IN COLD ENVIRONMENT

For summary, see Water Resources Research Catalog **6**, 8.0424.

318-0258W-370-00

CONTROL AND PREVENTION OF CULVERT AND ROAD ICING

For summary, see Water Resources Research Catalog **6**, 8.0426.

318-06387-870-00

THE EFFECTS OF THERMAL POLLUTION ON RIVER ICE CONDITIONS

(*c*) W. F. Weeks, Research Geologist.
(*d*) Field and theoretical.
(*e*) Measure temperature changes in the North Platte River, Wyo., below a large steam power plant. Relate heat dissipation to meteorological conditions to verify a theoretical model.
(*f*) Completed.
(*g*) A theoretical model on heat dissipation to meteorological conditions was developed.
(*h*) **The Effects of Thermal Pollution on River Ice Conditions,** S. L. Dingman, Y-C Yen, *USACRREL Research Report 206.*
The Effects of Thermal Pollution on River Ice Conditions, S. L. Dingman, W. F. Weeks, Y-C Yen, *Water Resour. Res.*, 1968.
Heat Transfer Coefficient for Calculation of a River Below a Thermal Pollution Source, A. Assur, S. L. Dingman, *USACRREL Research Report.*

318-06991-440-00

THE TEMPERATURE STRUCTURE OF A MID-LATITUDE DIMICTIC LAKE DURING FREEZING, ICE COVER, AND THAWING

(*c*) Mr. W. H. Parrott, Research Physicist.
(*d*) Field project.
(*e*) A small mid-latitude lake was instrumented primarily for temperature at 24 points at a vertical section at the deepest point in the lake. These data were taken every hour at all points. These data were analyzed during the periods of freeze-up, ice cover, and thaw. The heat balance of the lake was determined for different thermal structures of the lake and different meteorological conditions. The temperature of the bottom muds was measured to determine the contribution of energy stored in the bottom.
(*f*) Completed.
(*g*) Data was gathered and collated into report listed under (h).

(*h*) **The Temperature Structure of a Midlatitude Dimictic Lake During Freezing, Ice Cover, and Thawing,** W. H. Parrott, Wm. Fleming, *USACRREL Research Report.*

318-08439-140-00

HEAT TRANSFER STUDIES IN A WATER-AIR BUBBLING SYSTEM

(*c*) Dr. Y-C Yen, Chief, Physical Sciences Branch.
(*d*) Basic research.
(*e*) Investigate the effect of bubble size, frequency, distribution, and height to area ratio on the heat transfer characteristics in a water-air bubbler system for the prevention or limitation of ice formation.
(*g*) An analytical model is being developed to describe the heat transfer process and its relation to the parameters in paragraph (e).

318-08440-470-00

MONITORING DEMONSTRATION BUBBLER SYSTEM FOR DULUTH HARBOR, MINNESOTA

(*c*) Mr. Kevin Carey, Research Civil Engineer.
(*d*) Applied research.
(*e*) The bubbler system was developed for Duluth Harbor to keep an ice-free area near the Seaway Port Authority of Duluth Dock. The principal investigator monitored the system to determine its effectiveness.
(*f*) Complete.
(*g*) Water temperature readings of the bubbler area were taken over a period of time in late winter. Estimates were made of the volume or weight of ice melted and the volume of heat required.
(*h*) **Performance of the Demonstration Bubbler System–Duluth Harbor, Minnesota,** K. Carey, *USACRREL Technical Memorandum*, Apr. 1971. .

DEPARTMENT OF THE ARMY, DIVISION HYDRAULIC LABORATORY, NORTH PACIFIC DIVISION, CORPS OF ENGINEERS, Bonneville, Oreg. 97008. H. P. Theus, Director.

320-00405-350-13

GENERAL MODEL STUDY OF ICE HARBOR DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) Ice Harbor Dam is located on the Snake River 9.7 miles upstream from the junction of the Snake and Columbia Rivers. Principal features include a powerhouse for six 90,000-kW generating units (initial installation is three units), a concrete gravity spillway with ten 50-foot wide bays, a navigation lock with net clear dimensions of 86 by 675 ft. and a maximum single lift of 103 ft., and facilities for passing fish upstream over the dam. The purpose of the general model study was to determine flow conditions before, during, and after construction of the project. A 1:100-scale, fixed-bed model reproduced pertinent structures and 2.7 miles of Snake River channel adjacent to the dam.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-00407-330-13

MODEL STUDY OF NAVIGATION LOCK FOR ICE HARBOR DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-00405 for description of project. The hydraulic system for filling the lock chamber consists of wall intake manifolds, a longitudinal culvert in each sidewall, 12- by 14-foot, reverse-mounted tainter culvert valves, and wall discharge manifolds leading to five bottom laterals. Twelve ports, six on each side, discharge from each bottom lateral; ports in adjacent laterals are offset for clearance of opposing jets. The total area of ports is 1.2 times culvert area at the valves. In emptying, flow enters the lateral ports and passes through 12- by 14-foot culverts which bend 90 degrees just upstream from the vertical-lift downstream lock gate. Flow is released from a river outlet located 450 ft. downstream from the stilling basin. The purposes of the model study were to check the original design and to develop improvements if necessary. A section of culvert adjacent to and including a single bottom lateral was reproduced in a 1:16-scale model. Principal features of the lock approaches, lock chamber, and hydraulic systems were reproduced in a 1:25-scale model.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-02662-350-13

GENERAL MODEL STUDY OF JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) John Day Dam is located on the Columbia River, 25 miles upstream from The Dalles, Oregon. The reservoir formed by the 5900-foot long dam provides 76 miles of slack water for navigation upstream to McNary Dam and 500,000 acre-feet of flood storage. The spillway, designed for a flow of 2,250,000 cfs, consists of twenty 50-foot wide bays separated by 12-foot wide piers. The crest gates (tainter), each 50 feet wide by 58.5 feet high, are operated by individual electric hoists. Sixteen 135,000 kW Kaplan turbines are to be installed initially in the powerhouse; ultimate installation 20 units with total capacity of 2,700,000 kW. The 86- by 675-foot navigation lock has a maximum single lift of 113 feet. Fish facilities include a powerhouse collection system, auxiliary water supply systems, and a 24-foot wide fish ladder with main sections sloped 1 on 10 on each side of the river. The purposes of the model study were to provide information concerning diversion methods, conditions for navigation and fish passage, water-surface elevations, and flow patterns for each phase of construction. A 1:80-scale model reproduced 2.9 miles of Columbia River channel and pertinent overbank topography adjacent to the dam.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-02666-850-13

MODEL STUDY FOR FISH LADDERS FOR ICE HARBOR DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-00405 for description of project. The facilities for fish include a powerhouse collection system and a fish ladder with auxiliary water supply system on both sides of the river. The main portion of the north fish ladder is 16 feet wide and has a floor slope of 1 on 10. The 24-foot wide south fish ladder slopes 1 on 16.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-03577-350-13

GENERAL MODEL STUDY OF LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) Lower Monumental Dam is located at Snake River mile 41.6, about 32 miles upstream from Ice Harbor Dam. Principal features include a powerhouse for six generating units (ultimate installation), a navigation lock with net clear dimensions of 86 by 675 feet and a maximum single lift of 103 feet, an 8-bay gravity spillway, and a 16-foot wide fish ladder on each side of the river. The purpose of the model study was to investigate flow conditions that

might occur during and after construction of the project. A 1:100 scale model reproduced approximately 2.4 miles of Snake River bed and overbank topography at the dam site.

(*f*) Tests completed; final report in preparation.

(*g*) See 1970 issue.

320-04504-350-13

GENERAL MODEL STUDY OF LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) Little Goose Dam, at Snake River mile 70.3, is the third in a series of multiple-purpose dams being constructed above the mouth of Snake River for power, navigation, and other uses. Salient features include an 8-bay spillway, a navigation lock 86 feet wide by 675 feet long (maximum lift 101 feet), a powerhouse for six units (initial installation three 135,000-kW generators), and a 20-foot wide fish ladder on the south shore. A model study was necessary to determine minimum excavation requirements, to verify structure locations, and to check the overall effects of these structures on navigation, power generation, and fish passage. A general model, constructed to a linear scale ratio of 1:100, reproduced the river channel and pertinent overbank areas for 1.35 miles upstream and 1.90 miles downstream from the project axis.

(*f*) Tests completed; final report in preparation.

(*g*) See 1970 issue.

320-04505-850-13

MODEL STUDY OF FISHWAY DIFFUSERS FOR LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) An existing 1:8-scale fishway diffuser model was revised so that two diffusion chambers were supplied by a single riser from the conduit. Included in the model were diffusers 3 and 4 and the common distribution well, the supply conduit, and a portion of the 16-foot wide south shore fish ladder that carried all flow which passed through the diffusion chambers. In the original design, a 7-inch wide control orifice was located 3.5 feet above the diffuser well floor, and 1.5 foot high ports admitted flow into the respective diffusion chambers. The information desired from this model includes; the orifice size required to provide 48 cfs through each diffuser with a head of 2 feet (supply conduit grade line minus tail-water elevation), a submergence of 4 feet (supply conduit grade line minus elevation of downstream weir adjacent to diffuser 3), and a conduit flow of 500 cfs; a family of rating curves for heads of from 0.5 feet to 6.0 feet and various submergences; and the effect on diffuser discharge of varying the conduit flow from about 50 cfs (only one diffuser) to 750 cfs while a constant head is maintained on the test diffuser.

(*f*) Tests completed; final report in preparation.

(*g*) Two diffuser floor plans and 12 orifice arrangements were tested in efforts to obtain uniform distribution of diffuser flow into the fish ladder. The most satisfactory arrangement was selected from the test results.

320-05068-350-13

MODEL STUDY OF SPILLWAY FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) See 320-04504 for description of project. A 3-bay section of the 8-bay spillway and stilling basin was reproduced in a 1:42.45-scale model. The purposes of the tests were to check performance of the original spillway and to develop revisions that would improve performance or reduce construction and maintenance costs.

(*f*) Tests completed; final report in preparation.

(*g*) See 1970 issue.

320-05069-330-13

MODEL STUDY OF NAVIGATION LOCK FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) See 320-04504 for description of project. The intake manifolds, longitudinal culverts (both in right wall), lock chamber, split lateral filling and emptying system, outlet culverts, and portions of the approach and outlet areas were reproduced in a 1:25-scale model. An alternative method for distributing flow to the lateral culverts from a central junction chamber was studied in an auxiliary 1:25-scale model of the lock chamber. The purposes of the studies were to check the suitability of the original design and to develop improvements if necessary.

(*f*) Tests completed; final report in preparation.

(*g*) See 1970 issue.

320-05070-350-13

MODEL STUDY OF SPILLWAY FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) Dworshak Dam, on the North Fork of Clearwater River will furnish 400,000 kW of power from three units (initial installation) and, ultimately, 1,060,000 kW from six units. The spillway consists of two 50-foot wide bays, with crest at elevation 1545, a chute, and a 114-foot wide, 271-foot long stilling basin at elevation 931. Three 9- by 12.5-foot regulating outlets, upstream from the tainter valves, and 11 by 17 feet downstream from valves, discharge on the spillway chute. Total capacity of the spillway and regulating outlets is 221,000 cfs at pool elevation 1604.9. Approximately 1.6 miles of river channel and pertinent overbank topography were reproduced in a 1:50-scale model to study the cofferdam and diversion tunnel. A section of forebay, the spillway, regulating outlets, stilling basin, powerhouse, tailrace, and exit channel were reproduced to determine hydraulic characteristics of these elements.

(*f*) Tests completed; final report in preparation.

(*g*) See 1970 issue.

320-05071-350-13

GENERAL MODEL STUDY OF LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) Lower Granite Dam, at Snake River mile 107.5, is 37.2 miles upstream from Little Goose Dam. The 8-bay spillway, with 50- by 60.5-foot control gates (tainter) and the 498-foot wide, 167-foot long nonbaffled stilling basin are designed for a maximum discharge of 850,000 cfs. The 6-unit powerhouse will have a capacity of 810,000 kW; initial installation 405,000 kW from three units. The 86- by 675-foot navigation lock will have a maximum single lift of 105 feet. Fish facilities include a powerhouse collection system, three pumps for additional attraction flow (2550 cfs) and one 20-foot wide fish ladder with floor slope of 1 on 10. A 1:100-scale general model reproduced the riverbed and pertinent overbank topography between Snake River miles 106.1 and 108.9 and successive phases of construction. Construction stages, powerhouse tailrace limits and depths, navigation lock approaches, flow conditions affecting fish passage, and project operations were to be studied in the model.

(*g*) The first-step cofferdam and diversion channel were satisfactory after the channel entrance was modified and rock groins to aid fish migrations were added. Embankment and excavation limits for construction phases were determined. The effects of several stages of erosion downstream from the original stilling basin were investigated, and an improved basin design was developed with estimated maximum erosion in the tailrace. Satisfactory energy dissipation was obtained with the stilling basin raised 4 ft. and a 9-ft. end sill (originally 11 ft. high). An

undesirable eddy existed between the north fishway entrance and the navigation lock wall. Several combinations of walls, fills, and training wall extensions were tried in efforts to develop satisfactory conditions at the north fishway entrance. Development of modifications to reduce nitrogen supersaturation caused by spillway discharges was begun. Preliminary results indicate that 12.5-ft. wide horizontal deflectors on the spillway ogee will produce stable "skimming flow" in the stilling basin for river flows up to the 10-year flood, and required energy dissipation will occur at high flows; see also 320-07120.

320-05315-350-00

MODEL STUDY OF REGULATING OUTLETS FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-05070 for description of project. The three regulating outlets, with intakes at elevation 1350, will operate under heads of from 95 feet at minimum pool elevation 1445 to 254.9 feet at maximum pool elevation 1604.9. Total outlet capacity will be 40,000 cfs at pool elevation 1604.9. Pressures, flow conditions, and discharge relationships were observed in a 1:25-scale sectional model that reproduced a portion of the forebay, the right conduit, and a section of the spillway chute. The purpose of the study was to check the adequacy of the original design and to develop revisions if necessary.
(*f*) Tests completed; final report in preparation.
(*g*) Four designs for a bellmouthed intake were studied. See 1970 issue for details.

320-05316-850-13

MODEL STUDY OF FISH LADDER FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-04504 for description of project. A 1:10-scale model was used for tests of a 20-foot wide fish ladder with floor slope of 1 on 10.
(*f*) Tests completed; final report in preparation.
(*g*) Velocities, flow patterns, and discharge relationships were determined in typical pools, flow-control section, and slot-type counting station.

320-05317-330-13

MODEL STUDY OF COLUMBIA RIVER, OAK POINT TO VANCOUVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Portland.
(*d*) Experimental; for design.
(*e*) The project will increase the navigation channel width from 500 feet to 600 feet and the depth from 35 to 40 feet between Columbia River miles 52 to 109 and from the mouth of Willamette River to Portland, Oregon. Project depths and widths will be maintained by a system of pile dikes and by dredging. Five separate movable-bed models with 1:300 horizontal and 1:100 vertical scales will be required to cover improvements in the Columbia River. The models will be used initially to check plans for constructing and maintaining the 40-foot channel. Later the models will be used to check operation and maintenance activities and new construction. The first two models include river miles 53 to 65 and 64 to 78, respectivly. Work on the remaining three models has not begun.
(*f*) Scheduled tests of river miles 53 to 78 completed; final report in preparation.
(*g*) Shoaling indexes, based on results with an uncontrolled 40-foot deep navigation channel, were determined for each improvement plan tested in the models. Satisfactory plans are being developed for all problem reaches covered by both models. Alternative proposals, which would be more acceptable to local interests in the Longview-Rainier area (mile 66), were tested and the benefits of these plans were determined.

320-05318-350-13

MODEL STUDY OF POWERHOUSE SKELETON UNITS FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-02662 for description of project. Proposed changes in the skeletonized powerhouse units called for placement of as much concrete in the powerhouse draft tubes as diversion requirements would allow. The proposed skeleton bay differed from the original contract plan and from that at the Dalles Dam, the only unit that had been model tested. The changes, which were necessary to meet an accelerated construction schedule, might have affected designs for powerhouses at Lower Monumental and Little Goose Projects. A typical skeletonized unit of the type to be used for diversion was reproduced to a scale of 1:25 in a flume with glass sides that allowed observation of flow within the test unit.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-07107-350-13

MODEL STUDY OF SECOND POWERHOUSE FOR BONNEVILLE DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Portland.
(*d*) Experimental; for design.
(*e*) The existing project includes an 18-bay spillway with vertical gates lifted by 350-ton gantry cranes, a powerhouse with total rated capacity of 518,000 kW from 10 main units and one station service unit, a navigation lock with net clear dimensions of 76 by 500 feet, and fish facilities on each side of the river. Head on the project varies between 30 and 70 feet. From four to ten additional units are proposed to utilize increased storage and peaking operations at upriver projects. A 1:100-scale fixed-bed model reproduces the existing structures, riverbed, and pertinent overbank topography between river miles 142.2 and 146.8. A remote controlled towboat and tow are used to evaluate the effect of additional power units on navigation. The purpose of the study is to confirm the site chosen for the second powerhouse and to study flow conditions affecting fish passage, navigation, and head on the project.
(*g*) Three structures and excavation plans were investigated. Tests of the recommended plan (with present lock and provision for a future lock on the Oregon shore and a 10-unit powerhouse on the Washington shore) were continued. Tests of deflectors on the spillway ogee to reduce nitrogen supersaturation and determinations of the effects of deflectors on flow conditions at the fishway entrances were begun; see also 320-07108.

320-07108-350-13

MODEL STUDY OF SPILLWAY GATE MODIFICATION FOR BONNEVILLE DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Portland.
(*d*) Experimental; for design.
(*e*) See 320-07107 for description of project. Additional pondage at Bonneville Dam will be required to accomodate water released by future increased power peaking of upstream dams. All spillway gates will be made 60 ft. high (some are 50 ft. high) to provide the necessary pondage, and 10 of the gates will have individual hoists to allow remote control. The present gates cannot be operated under certain conditions because of vibration and a tendency to bounce. Remote control of spillway gates requires no known restrictions on spillway operation. A 1:25-scale model included one spillway bay, two half piers, one spillway gate, and a 60-ft. wide section of stilling basin and adjacent approaches. The gate was free to move vertically in the gate slots. The study was extended to include the hydraulic characteristics of deflectors between the

piers on the spillway ogee. These devices may reduce nitrogen supersaturation by causing air entrained by small to moderate spillway discharges to remain near the water surface. Purposes of the studies are to check performance of existing gate bottoms and proposed deflectors and to develop improved designs if required.

(*g*) The original gate bottom and six alternative shapes were investigated. Flow control shifted rapidly between the bottom seal and upstream face of the existing gate. The shifting control and resulting changing forces on the gate bottom made the gate vibrate vertically in the gate slots. Alternative gate shapes had varied vertical distances between the bottom of the upper face and the horizontal seal. A distance of 2.61 ft. between the bottom seal and the bottom of the upstream skin plate was recommended. With this design, vertical vibrations of the prototype gate will be negligible. Continuous horizontal deflectors 6-, 10-, 12-, and 15-feet wide were investigated. The selected 12-foot width was tested at elevations 12, 14, and 17. With the deflector at elevation 14, flow conditions in the stilling basin and pressures on the deflector were satisfactory for normal tailwater elevations and spillway flows to 10,000 cfs per bay.

320-07109-350-13

MODEL STUDY OF INCREASED POOL ELEVATIONS AT SPILLWAY OF CHIEF JOSEPH DAM, COLUMBIA RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Seattle.

(*d*) Experimental; for design.

(*e*) The existing project, located 51 miles below Grand Coulee Dam and 545 miles from the mouth of Columbia River, includes an excavated channel leading to an intake for 27 penstocks, a 20-unit powerhouse (initial installation 16 Francis turbines), and a spillway with nineteen 40-ft-wide bays surmounted by 9-ft-wide piers and 56.2-ft-high tainter gates. The spillway ogee was designed for a head of 41.6 ft on the crest, or 75 percent of the computed maximum total head of 55.4 ft at the project design flow of 1,250,000 cfs. Construction of a third powerhouse at Grand Coulee Dam will require additional storage and power units at Chief Joseph to use the increased flow. Present plans include raising the Chief Joseph pool from existing elevations 946 to maximum elevations 970, or up to 1.7 times the design head. Preliminary data on surge characteristics at the spillway were obtained in an existing spillway model that contained a standard high dam crest and piers with elliptical noses. The most suitable modifications (13-foot thick piers, 36-foot wide bays, gate radius 55 feet, gate trunnions at elevation 920 and 61.83 feet from existing crest axis) were studied in a 1:43.35-scale model. Water-surface elevations at the outlet of a 4-foot diameter relief tunnel in the right training wall were determined for uniform and varied operations of spillway gates during spillway flows of 50,000 to 550,000 cfs (powerhouse discharge 250,000 cfs).

(*f*) Tests completed; final report in preparation.

(*g*) The tests indicated that the original crest and stilling basin would be satisfactory. Surging of flow on higher, narrower spillway gates was severe at large partial gate openings. This unstable periodic surge resulted from the combined effects of structural geometry, large heads, and gate openings required to release desired flows. Surging in the narrow bays was reduced from a maximum of 10.8 feet (pool elevation 961.2 and gates open 35 feet) to 2.8 feet by suppressors that extended 4 feet from the side of each pier above the maximum nappe at free flow. Closing the right spillway gate allowed the relief tunnel to drain until the river discharge exceeded 800,000 cfs. A vertical deflector projecting 2 feet from the training wall just upstream from the relief tunnel outlet would reduce water levels in the tunnel and allow uniform spillway operation for most discharges.

320-07110-350-13

MODEL STUDY OF CONDUIT ENTRANCES FOR DWORSHAK DAM, IDAHO, AND LIBBY DAM, MONTANA

(*b*) U.S. Army Engr. Dist., Walla Walla and Seattle.

(*d*) Experimental; for design.

(*e*) Normal reservoir outflows at Dworshak and Libby Dams will discharge on the respective spillway chutes through conduits that operate under heads up to 250 feet on the regulating valves (tainter). Although conduit dimensions upstream from the valves differ (9 by 12.5 feet at Dworshak and 10 by 17 feet at Libby), the same type of bellmouthed intake will be used at both dams. The tentatively adopted "no-skew" intakes that were developed during the Dworshak conduit model study extended upstream beyond the face of the dam. This would have complicated design and use of unwatering bulkheads. A regulating conduit with streamlined entrance and a portion of forebay were reproduced in a 1:20-scale model for measurements of discharges, pressures, and other data. The purpose of the study was to develop revisions that could be used at Dworshak, Libby, or other projects.

(*f*) Tests completed; final report in preparation.

(*g*) Three designs for short, skewed, bellmouthed entrances for the Dworshak and Libby conduits were tested. Satisfactory plans for both entrances were developed.

(*h*) **Skewed Entrance for High-Head Conduits,** *Engineer Technical Letter No. 111-2-41*, Dept. of the Army, Office of the Chief of Engrs., Washington, D.C., May 1968.

320-07111-850-13

MODEL STUDY OF FISHWAY DIFFUSER FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) See 320-05070 for description of project. Adult fish will be attracted into a collection channel leading to a holding pool from which they will be transported to a hatchery, to the reservoir, or to another stream. Water for operation of the fish facilities will be pumped from tailwater, and distributed by means of six diffusion chambers into the collection system holding pool, and hopper pool. A typical diffusion chamber and portions of the adjoining supply conduit and collection channel were reproduced in a 1:10-scale model. Flow in the conduit varied from 100 to 480 cfs, diffuser discharge was 60 cfs, and a differential head of 2.5 feet existed between the supply conduit and collection channel. The purposes of the study were to check the adequacy of a typical diffusion chamber and to develop revisions if required.

(*f*) Tests completed; final report in preparation.

(*g*) See 1970 issue.

320-07112-850-13

MODEL STUDY OF HATCHERY JET HEADER FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) See 320-05070 for description of project. A new type of rearing pond, developed by the U.S. Fish and Wildlife Service, will be adapted for use at the Dworshak fish hatchery. Circulation in each pond will be provided by two jet headers that discharge between 70 and 400 gpm (0.17 to 0.89 cfs). One header, constructed full-scale of aluminum pipe, was attached to an existing water supply, tank, and weir box. The purpose of the study was to determine head-discharge relations and jet velocities for 1-1/4 and 1-inch nozzles.

(*f*) Tests completed; final report in preparation.

(*g*) See 1970 issue.

320-07113-330-10

MODEL STUDY OF HIGH HEAD NAVIGATION LOCK

(*b*) Office, Chief of Engineers.
(*d*) Experimental; applied research.
(*e*) The 1:25-scale model of the filling and emptying system for Lower Granite lock was modified for tests with lift heights other than that for which the lock was designed (105 feet). See 320-05071 for description of project. The purpose of the tests was to provide additional information about this new type of hydraulic system (central distribution to eight longitudinal culverts in lock chamber). The proposed work included filling tests with initial heads of 70, 80, and 90 foot, 4- and 8-barge tows, 1 and 2 valves operating, and cushion depths of 15, 17, and 20 feet.
(*f*) Suspended.

320-07114-850-13

MODEL STUDY OF REVISIONS FOR FISH LADDERS AT JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-02662 for description of project. Based on tests in a previous model (3578 in 1970 issue of HRUSC), an 18-pool submerged orifice regulating section was developed for the north fish ladder. The design incorporated a horizontal counting station between the fixed weir and regulating sections. A similar type of regulating section was used in the south ladder; a vertical-board-type counting station was located in the sloping portion of the ladder. Difficulties with passage of fish (especially shad) led to studies of vertical-slot regulating sections for both the north and south ladders. A 1:10-scale model was used for tests of 23 pools of the north fish ladder and then the exit, regulating section, auxiliary water diffusion chamber, fish counting station, and eight typical pools downstream from counting station. The model was used to check proposed revisions and to develop modifications if required. Similar tests were made for the south ladder where the design differed from the north ladder.
(*f*) Tests completed; final report in preparation.
(*g*) A new, very effective design of vertical-slot regulating section incorporating twice the usual number of pools with a maximum water surface drop of 6 in. per pool was developed. After full-scale test of six pools with fish in the National Marine Fisheries Service Laboratory, North Bonneville, Wash., the south ladder at John Day was modified to this design. After a full season of very successful fish passage, the north ladder also was revised.

320-07115-330-13

MODEL STUDY OF NAVIGATION LOCK FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-02662 for description of project. The 86- by 675-foot lock chamber, culvert system, and portions of adjacent approach channels were reproduced in a 1:25-scale model. The purpose of the study was to determine the most advantageous design for the filling and emptying system from the standpoints of rate of operation, degree of turbulence, and economy.
(*f*) Tests complete; final report in preparation.
(*g*) See 1970 issue.

320-07116-350-13

MODEL STUDY OF SPILLWAY FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-02662 for description of project. A three-bay section of the 20-bay spillway and stilling basin was reproduced to a scale of 1:41.143. In supplemental investigations, two low spillway bays (diversion stage of construction), a section of stilling basin, and portions of adjacent river channel were reproduced in a 1:24-scale model. The purposes of the tests were to check original and modified designs for the spillway and stilling basin.
(*f*) Tests completed; final report in preparation.
(*g*) Satisfactory designs for the spillway and stilling basin were derived. See 1970 issue for further details.

320-07117-350-13

MODEL STUDY OF SPILLWAY FOR LIBBY DAM, KOOTENAI RIVER, MONTANA

(*b*) U.S. Army Engr. Dist., Seattle.
(*d*) Experimental; for design.
(*e*) Libby Dam, at Kootenai River mile 219, 17 miles upstream from Libby, Montana, will include a spillway with two 48-ft wide bays with crests at elevation 2405, three 10- by 17-ft. regulating outlets, and a powerhouse for eight Francis units (ultimate installation 840,000 kW). Three powerhouse units (total capacity 315,000 kW) will be installed initially. At maximum pool elevation 2459, spillway capacity will be 145,000 cfs and total capacity of regulating outlets will be 61,000 cfs. The 116- by 300-ft. stilling basin, at elevation 2073, is designed for a maximum spillway discharge of 50,000 cfs. A 1:50-scale model reproduced a portion of the forebay, all hydraulic elements of the spillway and powerhouse, and 1600 ft. of exit channel. The initial purpose of the model was to check the adequacy of the spillway, regulating outlets, stilling basin, and excavated outlet channels. The scope of the study was increased to include tests of diversion plans and flow conditions with a powerhouse selective withdrawal structure.
(*g*) The model tests showed that the original spillway abutments, center pier, chute, and stilling basin were not satisfactory. During development tests, the bulkhead slots and upstream projections of pier and abutments were eliminated and the circular abutments were changed to elliptical. The center pier was narrowed from 24 to 20 ft., and both sides of the pier were tapered. A tapered extension of the center pier was used to reduce undesirable rooster tail in flow down the chute. The original stilling basin was 120 ft. wide and 172.8 ft. long at elevation 2074, and the basin walls were at elevation 2127. The adopted basin is 116 ft. wide, 300 ft. long, at elevation 2073, and the sidewalls are at elevation 2142. Sizes of rock needed for riprap in exit areas were determined. Six diversion plans were studied before an acceptable plan was selected. Several types of deflectors to prevent debris from lodging against the legs of a contractor's tower were investigated for flows greater than 50,000 cfs during second-stage construction. The adopted plan consisted of two concrete piers 15 ft. high and 87 ft. long. Each pier acted as a deflector and later would become part of the mass concrete monolith. Tests of the selective withdrawal structures indicated that overflow bulkheads on the face of the intake must be submerged about 20 feet to supply the turbine unit flow of 5800 cfs at pool elevation 2459. The pier nose shapes were revised and a floating skimmer device was developed to prevent vortex action and air entrainment at intakes of the selective withdrawal structure. Tests with a density-stratified reservoir are in progress.

320-07118-350-13

MODEL STUDY OF OUTLET WORKS FOR LOST CREEK DAM, ROGUE RIVER, OREGON

(*b*) U.S. Army Engr. Dist., Portland.
(*d*) Experimental; for design.
(*e*) Lost Creek Dam on the Rogue River will provide 315,000 acre-feet of usable storage for flood control and other uses and 49,000 kW of electric power. A multiple-use intake tower with openings at four levels will lead to a 15-foot diameter penstock and to a 12.5-foot diameter regulating outlet. A 6- by 12-foot bypass will permit reservoir releases through the penstock when the intake tower is un-

watered. The spillway will include three 45-foot bays. Design discharges are as follows; outlets works 9860 cfs at minimum pool elevation 1812, and 11,460 at maximum pool elevation 1872; bypass 2000 cfs; spillway 158,000 cfs. A 1:40-scale model reproduces a portion of forebay, the multiport intake tower, regulating outlet intake, valve section, conduit and stilling basin, penstock intake and tower bypass, penstock, powerhouse, and section of exit channel. Flow conditions and pressures in the bypass and penstock were studied in a separate 1:40-scale model. The purposes of the study are to investigate flow condtitions and pressures in the intake tower, regulating outlet, and penstock, to measure discharges through regulating valves and bypass intake, and to determine performance of stilling basin, tailrace, and downstream channel. A flip-bucket energy dissipator, designed to eliminate air entrainment and nitrogen supersaturation that occur with a conventional stilling basin also will be studied.

(*g*) Flow conditions and pressures in both models were satisfactory after an 80-foot section of the chute walls was raised to prevent overtopping during the design discharge.

320-07119-850-13

MODEL STUDY OF FISH LADDER FOR LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-05071 for description of project. The 1:10-scale model included weirs at the upper end of the 20-foot wide, 1-on-10 slope ladder, followed in turn by a 17-foot long diffuser pool, the 1-on-32 slope regulating section with 10 orifice and slot bulkheads on 16-foot centers, the 6-foot wide exit channel, and a section of forebay. The purposes of the investigation were to determine the adequacy of the proposed orifice-slot control section and to develop improvements if required.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-07120-350-13

MODEL STUDY OF SPILLWAY FOR LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 320-05071 for description of project. The 1:42.47-scale model included a 3-bay section of the 8-bay spillway, stilling basin, and approach channels. The study was expanded to include the hydraulic characteristics of horizontal deflectors with and without dentates on the spillway ogee. These devices may reduce nitrogen supersaturation by causing air entrained by small to moderate spillway discharges to remain near the water surface in the stilling basin. The purposes of the model are to check designs for the spillway crest, piers and abutments, chute, stilling basin, excavated channel, deflectors on the spillway ogee, and to develop revisions if required.
(*g*) No revisions of the original crest and piers were required. Discharge rating curves for both free and gated flows were obtained. Satisfactory agreement was not obtained between tailwater-jump curves measured in the spillway model and in the general model (study 5071). Return flow into the stilling basin from the powerhouse tailrace and expansion of flow along the lower lock guard wall were responsible for the differences. The final design for the stilling basin will be based on tests in the general model. Tests in the spillway and general models indicate that a 12.5-foot wide horizontal deflector at elevation 630 (crest elevation 681) will produce desired stable, shallowly aerated, "skimming flow" in the stilling basin for spillway discharges to 10,000 cfs per bay. Skimming action was improved by adding three rows of 1.8- by 2.6-ft dentates to ogee and deflector. Pressures on the deflector were positive. Cavitation may develop on the dentates. Use of deflectors and dentates does not reduce the energy dissipating capability of the stilling basin at high flows.

320-07121-330-13

MODEL STUDY OF NAVIGATION LOCK FOR LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental for design.
(*e*) See 05071 for description of project. In the unusual hydraulic system, a central junction chamber connects both longitudinal culverts to eight symmetrically-located longitudinal port manifolds (four upstream and four downstream) in the floor of the lock. There are six pairs of ports in each manifold. A 1:25-scale model reproduced a portion of the forebay and floating guide wall, the hydraulic system, the lock chamber, and portions of exit areas and downstream approach. The purposes of the investigation were to check the adequacy of the proposed design and to develop modifications if required.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-07122-850-13

MODEL STUDY OF FISH LADDERS FOR LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 03577 for description of project. Each of the two fish ladders is 16 feet wide and is constructed with a floor slope of 1 on 10. The partial overflow weirs are 6 feet high, have a 6-foot long baffle or nonoverflow section in the center, and have two 18- by 18-inch orifices at the floor. A 55-pool tangent portion of the proposed fish ladder was reproduced in a 1:10-scale model to obtain discharge data, to check flow stability, flow patterns, and velocities, and to develop revisions if needed.
(*f*) Tests completed; final report in preparation.
(*g*) Flow patterns within the pools were stable and approximately symmetrical except through the transition from plunging to full shooting flow. This transition will occur at heads and discharges greater than the normal head (12 in.) and discharge (70 cfs). There was no surge action in the model for simulated heads of 3.2 to 18 inches on the weirs.

320-07123-330-13

MODEL STUDY OF NAVIGATION LOCK FOR LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) See 03577 for description of project. Except for the intake manifolds, which are staggered in the upstream channel, essential features of the hydraulic system are similar to those previously model-tested and adopted for use at John Day Dam. The 1:25-scale John Day lock model was revised for this study by using the longitudinal culvert intake (John Day elevation 114 = Lower Monumental elevation 396) for elevation control, installing new upstream culvert transition and intake manifolds, and lowering the approach floor 4 feet for correct depth at intakes. The main purpose of the model study was to obtain acceptable flow conditions (no vortex formation) over the intake manifolds. Pressures in the culvert and hydraulic loads on a proposed revision of the lock emptying valves (skin plate upstream) were measured in the Lower Granite lock model.
(*f*) Tests completed; final report in preparation.
(*g*) See 1970 issue.

320-07124-300-13

MODEL STUDY OF PALOUSE RIVER CHANNEL IMPROVEMENT AT COLFAX, WASHINTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) The project provides a system of protective levees and improved channels for the main stem and the North and South Forks of Palouse River in Colfax, Washington. Most of the improved channel is concrete-lined and constructed

with steep bottom slopes and sharp horizontal curves that will cause supercritical flow, standing waves, and superelevation. The study was made in a 1:40-scale model in a plywood flume that reproduced 6570 feet of the South Fork, 3780 feet of the main stem and North Fork, existing bridges, and proposed elements of the improved channel. The purpose of the study was to check flow conditions with the improvement plan and modify the design if necessary.

(*f*) Completed.

(*h*) **Channel Improvement, Palouse River, Palouse, Washington,** R. L. Johnson, L. Z. Perkins, *Div. Hydr. Lab. Tech. Rept. No. 91-1*, June 1970.

320-07125-350-13

MODEL STUDY OF OUTLET WORKS AND TUNNEL FOR RIRIE DAM, WILLOW CREEK, IDAHO

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental, for design.

(*e*) Ririe Dam will be a rock-fill structure 184 feet high. Unlined approach and discharge channels will flank a gated spillway in the right abutment. The dam will create a reservoir with about 100,000 acre-feet of storage for flood control and irrigation. The outlet works include an intake tower, control valves, a conduit about 1190 feet long, and a stilling basin. A 1:25-scale model reproduces a portion of the forebay, the intake tower, regulating valves, conduit, stilling basin, and a section of exit channel. The purposes of the study are to check the possibility of vortex formation at the intake, to observe flow conditions, to obtain discharge rating curves, to measure pressures and head losses at critical locations, and to check stilling basin design.

(*f*) Completed.

(*h*) **Outlet Works and Stilling Basin, Ririe Dam and Reservoir, Willow Creek, Idaho,** L. Z. Perkins, P. M. Smith, *Div. Hydr. Lab. Tech. Rept. No. 131-1*, Jan. 1972.

320-07127-350-13

MODEL STUDY OF SPILLWAY AND OUTLET WORKS FOR WYNOOCHEE DAM, WYNOOCHEE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) The project, located on the Wynoochee River 51.8 miles above its confluence with the Chehalis River, will provide a reservoir with a usable capacity of 59,500 acre-feet of storage for flood control, domestic use, irrigation, and other purposes. The concrete , gravity-type dam will be 175 feet high. A chute spillway, designed to pass 52,500 cfs, will be located in the left abutment. The outlet works include a multilevel intake for two sluices, controlled by 7- by 8.5-foot slide gates, that discharge up to 9000 cfs over an unsubmerged flip bucket into the river channel. A portion of the forebay, the downstream ends of the spillway chute and regulating sluices, the flip bucket, and 720 feet of river canyon downstream from the dam were reproduced in a 1:40-scale model. The purposes of the model study were to develop a satisfactory outlet works, to determine excavation requirements in the downstream channel, to define the tailwater curve, and to check the spillway chute design.

(*f*) Completed.

(*h*) **Spillway Chute and Sluice Outlets, Wynoochee Dam and Reservoir, Wynoochee River, Wash.,** T. D. Edmister, P. M. Smith, *Div. Hydr. Lab. Tech. Rept. No. 134-1*, Feb. 1971.

320-08441-850-13

MODEL STUDY OF FISH LADDER MODIFICATIONS AT BONNEVILLE DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Portland.

(*d*) Experimental; for design.

(*e*) See 07107 for description of project. The upstream portions of existing fish ladders must be modified to accomodate daily forebay fluctuations due to future upriver power peaking and operation of additional power units at Bonneville Dam. The purpose of the study is to investigate in a 1:14-scale model the hydraulic operation of exit control sections, counting and public viewing sections, auxiliary water-supply intakes and conduits, and revised overflow weirs in the Bradford Island and Washington Shore fish ladders.

(*g*) Tests of alternative designs for a vertical-slot-type exit control section and counting station for the Bradford Island ladder are in progress.

320-08442-850-13

FISH HATCHERY AERATOR AND DEAERATOR TESTS

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) Filtered water, aerated, deaerated, and temperature regulated, will be recirculated through systems of headers and nozzles into rearing and holding ponds of several fish hatcheries that are being installed by the Corps of Engineers. Each pair of nozzles is designed to discharge 250 gpm (125 gpm per nozzle). One bank of 28 pairs of aerator nozzles (total discharge 7000 gpm) will be supplied by a 16-inch header pipe. Another bank of 16 nozzles (4000 gpm) will be supplied by a 12-inch header. Two banks of deaerators will be supplied by 6- and 8-inch headers (respective discharges 750 and 1000 gpm). Equal pressures are desired in both sets of headers. The purpose of the investigation was to calibrate aerator and deaerator systems of commercial black iron and PVC plastic pipe.

(*f*) Tests completed; final report in preparation.

(*g*) Pressures, discharges, and air demands were measured for four sizes of aerator pipe. Pressures and discharges were determined for four sizes of deaerator pipe.

320-08443-350-13

MODEL TESTS OF RELIEF PANEL FOR SELECTIVE WITHDRAWAL GATES AT DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) See 05070 for description of project. Selector gates of the multi-level power intakes will have 90 pressure relief panels per power intake to protect the gates against failure from internal waterhammer or excessive differential pressures caused by misoperation of the gates or power units. The panels will consist of butterfly valves mounted on torsion bars. A 1:5-scale model was used to determine torque on the shaft of a 1- by 4-foot panel and discharge for various openings under differential heads of 3 to 20 feet. The data were needed to verify and supplement design computation.

(*f*) Tests completed.

(*g*) Torque and discharge were measured for panel openings of 10, 20, 30, 40, and 45 degrees and heads of approximately 3 to 20 feet. Torque decreased with panel opening until a negative value was reached at an opening of 47 degrees. The maximum torque, 1869 foot-pounds, was measured at a differential head of 18.37 feet and a panel opening of 10 degrees.

320-08444-350-13

MODEL STUDY OF POWERHOUSE SKELETON UNIT FOR LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.

(*d*) Experimental; for design.

(*e*) See 05071 for description of project. A 1:40-scale model reproduced a proposed powerhouse skeleton unit and sections of approach and exit channel. The study was to determine the maximum discharge as limited structurally that could be released through a unit without entraining air and causing or increasing nitrogen supersaturation of

flow passing the project, and the best method of controlling the discharge. A skeleton unit with water passages nearly complete but without turbine will also be tested.

(*g*) Initially, the operating gates were tested as flow controls. Then the gates in combination with stoplogs in the gate and intake slots were investigated. From these studies, a bulkhead with slots or converging tubes was developed for prototype tests in a similar unit at Little Goose Dam during the spring freshet in 1971. Slots in the top seven rows were 4 inches high; the lower eight slots were 6 inches high (area 95 sq. ft.). The slot tubes converged on slopes of 1 on 4.27 and 1 on 4.78, respectively. The skeleton unit discharged 21,200 cfs (discharge coefficient 0.932) under 99 feet of Positive pressures were measured within the converging tubes and on the piers at the operating gate slots. Flow conditions within the skeleton bay were turbulent but satisfactory. Full-height, 12-inch deflectors attached to the left faces of intake piers reduced upwelling in the left downstream corner of the bay. Measurements at Little Goose Dam showed no increase in nitrogen supersaturation in flow downstream from a bulkhead skeleton unit.

320-08445-350-13

MODEL STUDY OF POWERHOUSE SKELETON UNIT FOR ICE HARBOR DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 00405 for description of project. The purpose of the study was to develp a satisfactory design for slotted bulkheads which would allow passage of the maximum flow through a skeleton unit without entraining air. Entrained air would cause or increase nitrogen supersaturation of flow passing the project. A 1:40-scale model reproduced an existing powerhouse skeleton unit and sections of approach and exit channel.
(*f*) Tests completed; final report in preparation.
(*g*) The original bulkhead design, which was based on the design developed in the Lower Granite skeleton unit model (08444), was not satisfactory when tested in the Ice Harbor model because of submergence differences. An alternative plan with three 8-inch, four 6-inch, and five 4-inch slots (bottom to top, area 84.5 sq. ft.), provided satisfactory control of turbulence and aeration and a discharge of 19,200 cfs per unit. Nearly unrestricted movement of operating gates when activating or deactivating the skeleton unit was possible.

320-08446-350-13

MODEL STUDY OF ORIFICE BULKHEADS FOR POWERHOUSE SKELETON UNITS AT JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 02662 for description of project. A 1:40-scale model that will reproduce an existing skeleton powerhouse unit and sections of approach and exit channel will be used to develop a satisfactory design for slotted-orifice intake bulkheads. These skeleton units differ from those tested for other projects in that more concrete has been added to the turbine bays. The bulkhead orifices will be sized to pass safely the maximum air-free discharge through a skeleton unit. A cover will be placed over the turbine bay in a second series of tests. Entrained air would cause or increase nitrogen supersaturation of flow passing the project.

320-08447-350-13

MODEL STUDY OF SPILLWAY FOR LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON

(*b*) U.S. Army Engr. Dist., Walla Walla.
(*d*) Experimental; for design.
(*e*) See 03577 for description of project. A 3-bay section of the 8-bay spillway and stilling basin were reproduced in a 1:42.47-scale model. The purpose of the tests was to determine details for a deflector that will be installed in one spillway bay of Lower Monumental before the spring freshet in 1972. Tests in the prototype are expected to indicate whether deflectors will reduce nitrogen supersaturation by causing air entrained by small to moderate spillway discharges to remain near the water surface in the stilling basin.
(*f*) Completed; final report in preparation.
(*g*) Deflector elevation 434 (crest elevation 483) and a 12.5-foot width were selected from model tests. The addition of three rows of dentates, one on the ogee immediately upstream from the deflector and two on the deflector, reduced air penetration into the stilling basin, stabilized the flow, and reduced the magnitude of surge in the zone of unstable flow.

DEPARTMENT OF THE ARMY, WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS, P.O. Box 631, Vicksburg, Miss. 39181. F. R. Brown, Engineer, Technical Director.

These project summaries are abridged from more detailed descriptions appearing in the Corps of Engineers "Annual Summary of Investigations in Support of the Civil Works Program."

321-00236-300-10

MISSISSIPPI BASIN MODEL

(*b*) Office, Chief of Engineers.
(*d*) Experimental; for design.
(*e*) Study the coordination of releases from reservoirs, investigate the effect of reservoir operation on flood stages, check the routing of project and other floods, establish and check levee grades, predict stages, and determine the effect of floodways on stage reduction. To study various reservoir operation procedures and their effects on downstream stages and discharges. To study various levee alignments and other structures in the flood plain and their effects on stages and discharges. See 1970 issue for model description.
(*g*) Testing was begun in February 1951, and various testing programs have been conducted on the model since that time for the Office, Chief of Engineers, Lower Mississippi Valley Division, Southwestern Division, Ohio River Division, Missouri River Division, various State agencies, and a few private businesses. Reports of tests have been published and most are available on loan from the library at the Waterways Experiment Station.

321-00425-300-13

DELAWARE RIVER MODEL STUDY

(*b*) Philadelphia District, North Atlantic Division.
(*c*) Thomas C. Hill, Estuaries Branch.
(*d*) Experimental; for design.
(*e*) Develop and test plans for reduction of shoaling in the Federal Navigation Channels; and to determine the probable effects of increasing the channel width and depth along with channel alignment changes on tides, current velocities, and salinities in the river. A comprehensive fixed-bed silt-injection model of the Delaware River with scale ratios of 1:100 vertically and 1:1000 horizontally was constructed. The model reproduces the entire tidal portion of the Delaware River beginning at the Capes and extending to Trenton. Tides, current velocities, and salinities are reproduced in the model along with the freshwater inflows.
(*g*) Numerous tests have been conducted to date in the Delaware River model. Results of completed tests have been presented in various reports published by WES. Tests to determine the effects of an extensive dike system enclosing all potential spoil disposal areas between Artificial Island and Philadelphia on tides, currents, salinities, and shoaling were completed; and preliminary results of the study were furnished the Philadelphia District for review. A series of thermal dispersion tests was conducted for the

Philadelphia Electric Company. The model was extended to include the Chesapeake and Delaware Canal and a portion of Chesapeake Bay and was used for the Chesapeake and Delaware Canal study.

321-00994-750-10

EFFECTS OF MODEL DISTORTION ON HYDRAULIC ELEMENTS

(*b*) Office, Chief of Engineers.
(*c*) J. J. Franco.
(*d*) Experimental; applied.
(*e*) Determine the hydraulic effects of various types and degrees of model scale distortion on velocity distribution and other hydraulic conditions, with the ultimate aim of establishing limits of permissible distortion for the various types of models. Tests have been conducted in a 5-ft-wide masonry flume having a 90-dg bend of 10-ft radius, with a straight approach channel 20 ft long and exit channel 60 ft long. A hypothetical stream to a horizontal scale of 1:200 and variable vertical scales to produce distortions up to 1:10 can be produced in the flume.
(*f*) Suspended.
(*g*) Tests to determine the effect of geometric distortion from 0 to 10 on a fixed-bed model have been completed. Tests to determine the effect of distortion and movable-bed models have been undertaken.

321-00998-420-10

WAVE FORCES ON BREAKWATERS

(*b*) Office, Chief of Engineers.
(*c*) R. W. Whalin.
(*e*) Conduct theoretical and experimental investigations of wave pressures and impact forces on vertical-wall and composite breakwaters from which the magnitude, duration, and location of forces on these structures, caused by breaking waves, can be determined with sufficient accuracy to ensure the design of safe and economical structures. A 2- by 5.5- by 140-ft concrete wave flume will be used for conducting experiments on shock pressures and total impact forces caused by waves breaking against vertical-wall breakwaters.
(*f*) Suspended.
(*h*) **An Experimental Study of Breaking-Wave Pressures,** *RR H-68-1*, Sept. 1968.

321-00999-430-10

STABILITY OF RUBBLE-MOUND BREAKWATERS

(*b*) Office, Chief of Engineers.
(*c*) R. W. Whalin.
(*d*) Experimental; applied.
(*e*) Develop design procedures and formulas, supported by experimental data, from which the design of safe and economical rubble-mound breakwaters can be determined. In addition to quarrystones, the investigation includes tests of tetrapods, tedrahedrons, tribars, quadripods, modified cubes, and other specially molded armor units. An experimental investigation is being conducted in a 5- by 4- by 119-ft wave flume. Present efforts are aimed at determining stability coefficients for the dolos armor unit on breakwater trunks for nonbreaking and breaking waves. Subsequent efforts will include tests on breakwater heads for the dolos and other concrete armor units.
(*g*) Preliminary data on the characteristics of a newly developed armor unit called "dolos" were determined. Stability tests for these new units using the no-damage, no-overtopping criteria on breakwater trunks subject to nonbreaking waves were completed for a breakwater slope of 1:1.5.
(*h*) **Design of Quadripod Cover Layers for Rubble-Mound Breakwaters,** *MP 2-372*, Jan. 1960.
Wave Forces on Rubble-Mound Breakwaters and Jetties, *MP 2-453*, Sept. 1961.

321-01002-750-10

EFFECTS OF SCALE AND OPERATING TECHNIQUES ON HARBOR WAVE ACTION MODELS

(*b*) Office, Chief of Engineers.
(*c*) R. W. Whalin.
(*d*) Experimental; theoretical.
(*e*) Obtain information which will allow more accurate determination of optimum scales for wave models, and the effects of different scales and operating techniques on the accuracy of model results. A general study is being conducted to determine effects of various model scales and distortion on wave characteristics in harbor and breakwater stability models. The effects on test results of various model-testing techniques are also being investigated. Screen filter tests were conducted in a 1- by 1.5- by 85-ft steel flume in which waves are generated by a hinged-plate type wave generator and are measured and recorded electrically.
(*h*) **Wave Damping Effects of Screens,** *RR 2-12*, March 1968.
Wave Damping Effects of Fibrous Screens, in progress.
Wave Reflection of Screen Absorbers, in progress.

321-01004-700-10

INSTRUMENTATION

(*b*) Office, Chief of Engineers.
(*c*) J. J. Franco.
(*d*) Experimental; development.
(*e*) Develop various types of measurements and control equipment for use in hydraulic models and in the field.
(*g*) Various instruments, unavailable from commercial sources, have been developed as the need has arisen. Current efforts are directed toward development of the boundary shear instrument, hydrogen bubble water velocity sensor, and the capacitive water-level sensor.

321-01467-390-10

DEVELOPMENT OF HYDRAULIC DESIGN CRITERIA AND COMPREHENSIVE DESIGN PROCEDURES

(*b*) Office, Chief of Engineers.
(*c*) E. B. Pickett.
(*d*) Analytical; for design.
(*e*) Analyze hydraulic data, theories, and procedures; to develop design criteria; to disseminate this information to the design offices of the Corps of Engineers to ensure adequate capacity, economy of design and construction, and safe and satisfactory operation of hydraulic structures built by the Corps. Field laboratory hydraulic data are collected from Government agencies, universities, professional and industrial papers, and reports. The results are analyzed and developed into design criteria, computer programs, engineer manuals, and special reports which are distributed to CE design offices.
(*g*) Calendar Year 1971–The 15th Issue of Hydraulic Design Criteria was distributed and two separates of the 16th issue separates were prepared. Twenty-one hydraulic design computer programs were prepared, documented as Category A programs, approved by OCE, and put in the WES system for use . Ten additional hydraulic design programs were prepared and put in the WES computer system. A report on tainter gate opening practice was prepared for publication. Engineer technical letters on combined sluice and spillway operation and on resistance losses in noncircular conduits were prepared.

321-01986-060-10

INVESTIGATION OF SALINITY INTRUSION AND RELATED PHENOMENA

(*b*) Office, Chief of Engineers.
(*c*) R. A. Sager.
(*d*) Analytical; experimental.
(*e*) Determine the effects of the physical and hydraulic features of estuaries on the extent of salinity intrusion, the nature of salinity intrusion, the magnitudes and durations

of current velocities, and other factors considered essential to proper solution of estuarine problems. The project consists of three broad phases. Definition of the range of conditions for which investigations appear desirable; flume tests to study the effects of the various factors involved; and analytical studies aimed at establishment of fundamental laws describing the phenomena involved.

(*g*) The state-of-the-art of the analytical solution to the problem was compiled showing that mathematical difficulties have not been overcome. Development of dimensionless correlations from laboratory and field data has resulted in significant advances in relation of velocity ratios and local densimetric Froude number, flow predominance concepts, estimation of shoaling patterns, development of an estuary number as an index of the relative degree of stratification in an estuary, and general improvement of the understanding of dispersity and general circulation patterns within the intrusion region. Information has been developed to provide rough conditions of an estuary.

(*h*) **One-Dimensional Analysis of Salinity Intrusion in Estuaries,** A. T. Ippen and D. R. F. Harleman, *TB No.5*, June 1961.
Two-Dimensional Aspects of Salinity Intrusion in Estuaries, D. R. F. Harleman and A. T. Ippen, June 1967.

321-01987-350-10

RIPRAP PROTECTION AT HYDRAULIC STRUCTURES

(*b*) Office, Chief of Engineers.
(*c*) Glenn A. Pickering.
(*d*) Experimental; applied.
(*e*) Develop design criteria for riprap at hydraulic structures. Data obtained from model tests of specific flood-control and navigation structures including low-head navigation dams, drop structures, and culvert outlets are being analyzed in an attempt to develop design rules regarding riprap protection.
(*g*) Tests have been conducted using models of specific structures of various scales to obtain basic data such as discharge, velocity, depth of flow, etc., when riprap failure occurs downstream from hydraulic structures. A plot relating Froude number, stone diameter, and depth of flow downstream from structures as well as in open channels has been made that could possibly be used in the design of riprap; however, additional data are needed to substantiate this plot before it can be recommended for design purposes.
(*h*) **Control of Scour at Hydraulic Structures,** *MP H-71-5*, Mar. 1971.

321-01988-220-10

WATER TEMPERATURE EFFECTS ON BED FORMS AND ROUGHNESS

(*b*) Office, Chief of Engineers.
(*c*) J. J. Franco.
(*d*) Experimental; applied.
(*e*) Determine the effects of water temperature on streambed forms and bed roughness of various types of bed materials. It has long been known that water temperature variations caused marked variations in the nature and rate of bed movement, which are of major significance in movable-bed model studies. The investigation of this phenomenon is being conducted in existing laboratory flumes, in which water temperatures can be varied to simulate normally experienced summer and winter temperatures.
(*g*) Tests with a fine-grained material and a coarse-grained material have been completed. Tests with a medium grain size material have been undertaken.

321-03907-220-10

SHOALING PROCESSES

(*b*) Office, Chief of Engineers.
(*d*) Experimental; for design.
(*e*) To determine means for reducing maintenance dredging costs in tidal waterways. Approaches are (a) flume studies of muddy sediments; (b) flume studies of repetitive scour and deposition; (c) develop radioactive sediment tracer techniques; (d) develop in-place turbidity meter; (e) study stabilization of deposits; (f) determine effects of flocculation; (g) correlation of field shoaling with significant parameters; and (h) classification of sediments.
(*g*) Item (a) above has been completed under terms of a contract between the University of California and the San Francisco District, and all pertinent reports have been published; item (c) has been completed under terms of a contract between the University of California and WES; under item (f), field studies of flocculation phenomena in Savannah Harbor and the Delaware Estuary were completed, analysis of the data obtained in Savannah Harbor was completed, and a report is ready for publication. Analysis of data obtained in the Delaware Estuary was continued in 1971. All other items listed above were inactive in 1971 because of nonavailability of laboratory facilities or the diversion of funds to more pressing research items.
(*h*) **A Study of Rheological Properties of Estuarial Sediments,** *Tech. Bull. 7*, Committee on Tidal Hydraulics.

321-03917-350-10

GENERAL SPILLWAY MODEL TESTS

(*b*) Office, Chief of Engineers.
(*c*) E. S. Melsheimer.
(*e*) Study hydraulic characteristics of spillways with heads as great as 60 ft, including the development of specific revisions to prevent surging of flow at the abutments and on tainter gates as well as determination of pier lengths that prevent separation of the nappe from the weir crest. A flume 70 ft long by 6 ft wide and 6 ft high comprises the test facility. Section models designed for study of particular elements of spillways are installed in the test flume.

321-04382-350-10

HYDRAULIC PROTOTYPE TESTS

(*b*) Office, Chief of Engineers.
(*c*) E. B. Pickett.
(*e*) Coordinate the hydraulic prototype testing program of the Corps in order to ensure complete coverage of needed testing, prevent unnecessary duplication of testing facilities and tests, recommend instrument installation at projects where physical and hydraulic conditions will be suitable for obtaining data, and investigate hydraulic performance. Assist Districts in planning and making hydraulic field tests, including planning and design of test facilities, making personnel and equipment available for tests, and analyzing data and preparing reports.
(*g*) Assistance was provided to 10 Districts for 11 projects during Calendar Year 1971.

321-04390-330-13

MODEL STUDY OF CANNELTON LOCKS AND DAM, OHIO RIVER, INDIANA AND KENTUCKY

(*b*) Louisville District, Ohio River Division.
(*c*) John J. Franco, Waterways Branch.
(*e*) Investigate navigation conditions in the lock approaches and effects of the structures on flood stages. Two models were used in this study. A 1:120-scale model reproduced about 9 miles of the river and adjacent overbank areas. A 1:25-scale model reproduced 500 ft of the lock approach channel, intake manifolds, the lock chamber, culvert, sidewall port manifolds, outlets, and 200 ft of the downstream exit channel. See 1970 issue for further details.
(*h*) **Filling and Emptying System, Cannelton Main Lock, Ohio River, and Generalized Tests of Sidewall Port Systems for 110- by 1200-ft Locks; Hydraulic Model Investigation,** *TR 2-713*, Feb. 1966.

321-04602-330-10

LOCK FILLING AND EMPTYING SYSTEMS

(*b*) Office, Chief of Engineers.
(*c*) J. H. Ables, Jr.
(*d*) Analytical and model; applied.
(*e*) Provide new or improved design information and procedures to assist in the design of navigation lock filling and emptying systems. Model and analytical studies are planned. Flumes with required appurtenances are available for testing, at scales of 1:25, filling and emptying systems of locks as large as 110 by 1200 ft with lifts of 100 ft.
(*g*) Information necessary to design side port filling and emptying systems for 110- by 1200-, 110- by 600-, and 84- by 600-ft low-lift locks have been reported, respectively, in WES Technical Reports 2-713, 2-743, and 2-678. Tests of the relative effects of several crossover culvert designs and floor culvert arrangements for a longitudinal floor culvert system for 110- by 600-ft locks with lifts of 69 ft were being analyzed. Data also were being analyzed at 50-, 90-, and 100-ft lifts for the best designs. Results of model tests on major elements of the longitudinal floor culvert system for 110- by 1200-ft locks are being reviewed. Data obtained on the longitudinal floor culvert system are being analyzed for 110- by 1200-ft locks. A literature search is under way for the purpose of collecting material for assisting in the design of end filling system for 110- by 600- and 1200-ft locks with low lifts. Tests of the longitudinal floor culvert system have been delayed in order to utilize the test facility for model tests of the 1200-ft Mississippi River Gulf Outlet for ships and barges.

321-05229-410-10

GENERAL COASTAL INLET STUDIES

(*b*) Office, Chief of Engineers.
(*c*) R. A. Sager.
(*d*) Experimental; laboratory and field; applied.
(*e*) Provide a basis for design of effective methods of improving tidal inlets as they relate to navigation through the inlet, transfer of sand past the inlet, and prediction of hydraulic and hydrographic changes to the inlet and embayment, and passage of storm surges through the inlet. The project consists of specific investigations of prototype inlets; extensive testing in physical models using both fixed and movable-bed techniques; investigation and development of mathematical models of all phenomena; and detailed analysis of all available data. Generalized test facilities at both the WES and CERC are utilized in the study.
(*g*) Data from prototype inlets have been obtained and analysis of the data to define the geometric variations of tidal inlets is under way. Preliminary definition of basic inlet geometry has been completed. Based on the inlet geometry of prototype inlets, an "idealized" inlet which is typical of prototype inlets has been developed. This inlet will form the initial inlet geometry for model tests to define the hydraulic characteristics of tidal inlets. Tests in the fixed-bed distorted-scale and movable-bed models of Masonboro Inlet have been initiated to define the applicability of each type of model in predicting the response of prototype inlet as well as to obtain a better understanding of the response of low weir and bypassing systems. Tests of potential movable-bed materials are under way with a series of tests with a 0.2-mm quartz sand completed. The tests included small 1/2- and 1/4-scale models of the laboratory tests to aid in development of scaling relations for movable-bed models.

321-05233-440-13

MODEL STUDY OF SUBMERGED SILLS, ST. CLAIR RIVER

(*b*) Detroit District, North Central Division.
(*e*) Study effects of number and location of submerged sills on discharge characteristics, navigation conditions, and sedimentation; and to investigate effects of shape of weir on discharge characteristics. A comprehensive fixed-bed model that reproduced 3.1 miles of the St. Clair River downstream from Lake Huron at a scale of 1:60 was used to study the effect of sills on lake level. A 1:20-scale section model in a 2.5-ft-wide flume was used to investigate shape and stability of individual sills.
(*f*) Final report in preparation.
(*g*) Submerged sills can be used to increase the level of Lake Huron from 0.25 to 0.75 ft.

321-05245-330-13

MODEL STUDY OF HOUSTON SHIP CHANNEL, TEXAS

(*b*) Galveston District, Southwestern Division.
(*c*) R. A. Boland, Jr., Estuaries Branch.
(*e*) Determine means for reducing present cost of maintenance dredging in the Houston Ship Channel. To investigate partial or complete diking of connecting bays, sediment traps, dikes in Galveston Bay, local contractions, enlargements, and other remedial measures. See 1970 issue for details.
(*g*) Satisfactory verification results were obtained by introducing shoal material (gilsonite) over the entire length of the channel. Results of tests to determine the effectiveness of a 1400-ft-wide (including the existing 400-ft-wide ship channel) by 12,000-ft-long sediment trap dredged to depths of both 50 and 60 ft indicate that the 50-ft-deep trap would reduce shoaling in the reach between Baytown to Morgan Point by about 49 percent, while the 60-ft-deep trap would reduce shoaling in the reach by 41 percent. Shoaling verification tests, assuming that shoal material is being supplied to the channel in the section from Morgan Point to Bolivar Roads only, are under way.

321-05246-330-13

UNIONTOWN LOCKS AND DAM, OHIO RIVER, MODEL STUDY OF NAVIGATION CONDITIONS

(*b*) Louisville District, Ohio River Division.
(*c*) J. J. Franco, Waterways Branch.
(*e*) Investigate navigation conditions with the proposed structures, to determine the effects of modifications in the composition and arrangement of the structures, and to develop any modifications considered desirable. See 1970 issue for details. Tests concerned with navigation conditions with a 10-gate dam and with the development of excavation plans near the head of Wabash Island were continued. Dam modifications to provide for a future third lock either landward or riverward of the existing locks were investigated.
(*g*) Satisfactory navigation conditions could be developed with the third lock landward of the existing locks.

321-05635-430-10

INVESTIGATION OF WAVE REFLECTING AND TRANSMITTING CHARACTERISTICS OF RUBBLE-MOUND BREAKWATERS, RUBBLE WAVE ABSORBERS, AND FLOATING BREAKWATERS

(*b*) Office, Chief of Engineers.
(*c*) R. W. Whalin.
(*d*) Theoretical, experimental; applied.
(*e*) Establish design criteria for rubble breakwaters with respect to their wave reflecting-transmission characteristics, and for different types of wave absorbers (natural sand beaches, wave traps, resonators, and rubble mound). A comprehensive study is being conducted to critically review the theoretical aspects of wave absorbers and show their application to practical situations; to develop more accurate methods of measuring wave reflection-absorption characteristics of short-period waves; to investigate the energy transmitted through and over rubble-mound structures; and to determine the wave absorbing characteristics of sand beaches, wave traps, resonators, and certain types of floating breakwaters. A 1- by 1.5- by 85-ft steel wave flume with a hinged-plate type wave generator was used for the wave transmission and reflection tests and a 1.0-cfs

pump circulating system was used for the permeability tests.

(*g*) Permeability tests were conducted on a vertical-faced rubble-mound rock section using 1/4-, 1/2-, 3/4-, 1-, 1-1/2, and 2-in. rock, respectively. Tests were also conducted to determine the wave energy transmission and reflection characteristics of two sloping-face rubble-mound breakwater structures, similar in size, shape, and impervious core section, but the core sections placed at different elevations.

(*h*) **Hydraulic Characteristics of Mobile Breakwaters Composed of Tires and Spheres,** *TR H-68-2*, June 1968.
Waterways Transmission Through and Reflection by Pervious Coastal Structure, *RR H-69-1*, Oct. 1969.

321-05644-330-13

NAVIGATION CONDITIONS IN LITTLE ROCK REACH, ARKANSAS RIVER

(*b*) Little Rock District, Southwestern Division.
(*c*) J. J. Franco, Waterways Branch, Hydraulics Division.
(*e*) Study navigation conditions through six bridges at Little Rock, Ark., to determine modifications required in the existing bridges; and to develop a plan of regulating structures required to provide satisfactory navigation conditions. Tests were conducted to determine modifications required at the six bridges to improve navigation conditions and training structures required to improve current alignment through the reach and eliminate shoaling downstream of the bridges.
(*f*) Final report in progress.

321-05648-470-13

MODEL STUDY OF BRUNSWICK HARBOR, GEORGIA

(*b*) Savannah District, South Atlantic Division.
(*c*) F. A. Herrmann, Estuaries Branch.
(*e*) Determine if the present high rate of shoaling in East River can be reduced by changing the distributions of flows, creating turbulence, increasing bottom velocities, or reducing the tidal prism of East River to a minimum. A fixed-bed model reproduced Brunswick, Turtle, and East Rivers, Jekyll Creek and St. Simons Sound to scales of 1:500 horizontally and 1:100 vertically. Tides, currents, and sedimentation were reproduced and studied.
(*f*) Final report in progress.

321-06020-330-13

MODEL STUDY OF LOCK AND DAM NO. 14, ARKANSAS RIVER

(*b*) Tulsa District, Southwestern Division.
(*c*) J. J. Franco, Waterways Branch.
(*e*) Investigate navigation conditions with the proposed structures, to determine the location and width of a navigation channel, and to develop a plan of regulating structures required to provide satisfactory navigation conditions. An undistorted, 1:120-scale, semifixed-bed model, reproducing approximately 3.4 miles of the Arkansas River and adjacent overbank area including Bruce Island and the Cherokee Chute and the lock and dam structures, was used for this investigation.
(*f*) Completed.
(*h*) **Lock and Dam No. 14, Arkansas River Navigation Project: Hydraulic Model Investigation,** *TR H-71-1*, Feb. 1971.

321-06022-330-13

MODEL STUDY OF LOCK AND DAM NO. 8, ARKANSAS RIVER

(*b*) Little Rock District, Southwestern Division.
(*c*) John J. Franco, Waterways Branch.
(*e*) Investigate various plans of regulating structures and to develop modifications as required for the development of a channel of adequate dimensions and satisfactory navigation conditions in the approaches to the lock. The investigation was conducted on a movable-bed model reproducing about 10 miles of the Arkansas River and adjacent overbank areas to a scale of 1:120 horizontally and 1:80 vertically.
(*f*) Final report in progress.

321-06025-420-13

TEXAS COAST HURRICANE SURGE MODEL STUDIES

(*b*) Galveston District, Southwestern Division.
(*c*) N. J. Brogdon and R. A. Boland, Estuaries Branch.
(*e*) To determine the effectiveness of hurricane surge protection plans for the Galveston Bay complex, including effects of the plan on bay circulation patterns, salinity, shoaling regimes, deep- and shallow-draft navigation, fish and wildlife, and pollution. Tests were conducted in four models to evaluate the effectiveness of protection achieved by the proposed plans for hurricane surges and the effects of each plan on modification of tides, currents, salinity, and circulation patterns for normal tides. See 1970 issue.
(*h*) Report 2, **Effects of Proposed Barriers on Tides, Currents, Salinities, and Dye Dispersion for Normal Tide Conditions: Hydraulic Model Investigation,** July 1970.
Report 2, Appendix A, **Dye-Time Concentration Curves,** July 1970.
Report 3, **Effects of Plan 2 Alpha and Plan 3 Gamma Barriers on Tides, Currents, Salinities, and Dye Dispersion for Normal Tide Conditions: Hydraulic Model Investigation,** July 1970.
Report 3, Appendix A, **Dye-Time Concentration Curves,** July 1970.

321-06027-330-13

MODEL STUDY OF GASTINEAU CHANNEL, ALASKA

(*b*) Alaska District, North Pacific Division.
(*c*) F. A. Herrmann, Estuaries Branch.
(*e*) Reduce shoaling in order to maintain a suitable navigation channel. Various dike layouts that will isolate the channel cut from the surrounding area were investigated. A physical fixed-bed model reproduced the westernmost 8 miles of Gastineau Channel and Fritz Cove to linear scales of 1:500 horizontally and 1:100 vertically. Tides, currents, and freshwater inflow significant to the movement and deposition of sediment were reproduced and studied.
(*f*) Preparation of the final report is in progress.

321-06042-300-13

INVESTIGATION OF PROPOSED DIKE SYSTEMS

(*b*) Memphis, Vicksburg, New Orleans, and Lower Mississippi Valley Division.
(*c*) J. J. Franco, Waterways Branch.
(*e*) Determine the effectiveness of proposed dike plans in stabilizing low-water channels and in providing the required increase in depth. The investigation is being conducted in a flume 150 ft long with a width varying from 30 to 90 ft. The study is of the movable-bed type with a fine, uniform sand used for bed material.
(*g*) The study resulted in the development of plans for regulating structures for the Wolf Island Bar reach of the Mississippi River.

321-06849-400-13

MODEL STUDY OF CHESAPEAKE BAY

(*b*) Baltimore District, North Atlantic Division.
(*c*) Thomas C. Hill, Estuaries Branch.
(*e*) The Estuaries Branch has been given the responsibility for assisting the Baltimore District in the design, construction, verification, and testing of a hydraulic model of the Chesapeake Bay. The model will be utilized to develop a master plan for use of the Chesapeake Bay and tributaries. A fixed-bed, comprehensive model of the Chesapeake Bay and tributaries with linear scale ratios of 1:100 vertically and 1:1000 horizontally will be constructed. The model will have the capability of reproducing tides, current

velocities, salinities, hurricane surges, and freshwater inflows. See 1970 issue for further details.

321-06859-330-13

MODEL STUDY OF SMITHLAND LOCKS AND DAM, OHIO RIVER

(b) Nashville District, Ohio River Division.
(c) J. J. Franco, Waterways Branch.
(e) Determine the optimum location and alignment of the locks and dam; to investigate shoaling and erosion tendencies; and to develop modifications which might be required to overcome any undesirable conditions. The investigation is being conducted on a 1:150-scale comprehensive model which can be converted from fixed to movable bed. The model reproduces the proposed structures and about 8.5 miles of the Ohio River and adjacent overbank area to the bluff lines. The model also reproduces a short reach of the Cumberland River above its junction with the Ohio River.
(g) Satisfactory navigation conditions and a channel of adequate dimensions have been developed for a 17-gate dam; tests of an 11-gate dam are in progress.

321-06861-330-13

MODEL STUDY OF ARKANSAS, VERDIGRIS, AND GRAND RIVERS CONFLUENCE

(b) Tulsa District, Southwestern Division.
(c) John J. Franco, Waterways Branch.
(e) Investigate various plans of regulating structures and to develop modifications required for the development of a channel of adequate dimensions and satisfactory navigation conditions in the vicinity of the confluence of the three rivers. A movable-bed model with scale ratios of 1:120 horizontally and 1:80 vertically reproduced the Arkansas River from about river mile 457 to 462.5, plus about 4000 ft each of the Verdigris and Grand Rivers and adjacent overbank areas.
(f) Final report in progress.

321-06862-330-13

MODEL STUDY OF VAN BUREN REACH, ARKANSAS RIVER

(b) Little Rock District, Southwestern Division.
(c) J. J. Franco, Waterways Branch.
(e) Study navigation conditions at the three bridges at Van Buren, Ark., to determine modification required in the existing railroad bridge, the interstate highway bridge under construction, and the proposed relocation of the highway bridge, and to develop a plan of regulating structures to provide satisfactory navigation conditions. See 1970 issue. Tests were conducted to determine the effects of various arrangements of regulating structures on navigation using the reach and on channel alignment and channel depth through the reach.
(g) The results have indicated the relative effectiveness of various plans proposed for the reach and the regulating structures required to develop a satisfactory channel.

321-06866-430-13

MODEL STUDY OF DESIGNS FOR JETTY REPAIRS, HUMBOLDT BAY, CALIFORNIA

(b) San Francisco District, South Pacific Division.
(c) D. D. Davidson, Wave Dynamics Branch.
(e) To investigate the waves that can attack the proposed structures; the effects on stability of linking the armor units; and the optimum shape of armor unit and repair section that would be stable for the selected design-wave conditions. Initially, repair sections were tested using cube-shaped blocks, tetrapods, tribars, and tri-longs; tests using dolosse were conducted near the end of the study when it was concluded that the size of tribar necessary to ensure stability for the design-wave conditions could not be placed at the required toe distance. A stability model study was conducted in the WES 250-ft-long by 50-ft-wide by 4.5-ft-deep flume. A model scale of 1:50 was selected and only the north jetty head was reproduced in the model. The seaward bottom topography was reproduced by molding a 2-in.-thick concrete-crusted slope of 1:50 from -66 to -48 ft mllw and a slope of 1:10 from -48 to -36 ft mllw. The immediate head was reproduced with an average of 12-ton stone from -36 ft mllw to the crest. Model waves were generated by a paddle-type wave machine, and were measured and recorded electrically.
(h) **Proposed Jetty-Head Repair Sections,** *TR H-71-8, Humboldt Bay, California; Hydraulic Model Investigation*, Nov. 1971.

321-06874-360-13

PROTOTYPE VALVE TEST, SUMMERVILLE LAKE, GAULEY RIVER, WEST VIRGINIA

(b) Huntington District, Ohio River Division.
(c) F. M. Neilson, Hydraulics Analysis Branch, Hydraulics Division.
(e) Determine whether or not the new Howell-Bunger valve would undergo a fatigue-type failure during prolonged operation, and to obtain some basic data pertaining to the dynamic response of a prototype Howell-Bunger valve. Of secondary consideration was the evaluation of hydraulic characteristics of the outlet conduit. Prototype measurements included both dynamic and time-averaged values of pressure in the flow and strain and acceleration at locations on the valve structure. Data reduction was by scaling oscillograph traces and by using electronic analog to perform linear spectral density, amplitude density, and cross-correlation analyses on the magnetic tape data.
(f) Completed.
(h) **Howell-Bunger Valve Vibration, Summersville Dam Prototype Tests,** *TR H-71-6*, Sept. 1971.

321-06875-220-10

RIPRAP REQUIREMENTS IN CHANNELS

(b) Office, Chief of Engineers.
(c) E. S. Melsheimer.
(e) Develop design criteria for riprap in channels. Theoretical and experimental investigations regarding the adequacy of various sizes of crushed stone and gravel in resisting flow in straight and curved reaches of trapezoidal channels of varying hydraulic radii will be conducted to obtain basic data for development of a satisfactory theory and appropriate design criteria regarding the stability of stone in flowing water. Laboratory facilities and a program of hydraulic model tests determining the adequacy of various sizes of stone in resisting flow in straight channels of varying hydraulic radii are being developed.

321-07155-350-13

MODEL STUDY OF SPILLWAY GATES, ARKANSAS RIVER DAMS

(b) Little Rock District, Southwestern Division.
(c) G. A. Pickering, Structures Branch.
(e) Verify the effectiveness of completed and proposed gate lip modifications on the Arkansas project in eliminating gate vibrations. A 1:12-scale model that reproduced one 60-ft-wide gate and the adjacent half bays was used to investigate the gate vibrations. The central gate reproduced the prototype with respect to size, shape, and weight, whereas the adjacent gates were only schematic. Prototype water-surface elevations and flow conditions were accurately reproduced in the model.
(f) Completed.
(h) **Spillway Gate Vibrations on Arkansas River Dams, Arkansas and Oklahoma: Hydraulic Model Investigation,** *TR H-71-5*, June 1971.

321-07156-350-13

MODEL STUDY OF OUTLET WORKS, BRANCHED OAK DAM, NEBRASKA

(*b*) Omaha District, Missouri River Division.
(*c*) B. P. Fletcher, Structures Branch.
(*e*) Verify the performance of the structure and particularly to ensure against undesirable flow characteristics, such as surging during transition of flow control from weir to conduit, which tend to incite excessive vibration of the structure. Tests were conducted on a 1:10-scale model that reproduced the outlet works, 10,000 sq ft of approach area, the 280-ft-long conduit, stilling basin, and 200 ft of the exit channel. Tests were conducted to investigate discharge characteristics of the weirs and flow in the elbow transitions, conduit, and stilling basin.
(*f*) Final report in progress.
(*g*) The outlet works for both Branched Oak and Cottonwood Springs were subjected to undesirable flow characteristics such as nappe flutter, sloshing, and gulping which tended to vibrate the structures. Model tests indicated sloshing could be eliminated by providing a divider wall between and parallel to the weir crests, and the gulping beneath the cover plate eliminated by placing the cover plate at an elevation above that of the upper pool when the conduit begins to control flow.

321-07157-350-13

MODEL STUDY OF CLARENCE CANNON DAM, SALT RIVER, MISSOURI

(*b*) St. Louis District, Lower Mississippi Valley Division.
(*c*) Bobby P. Fletcher, Structures Branch.
(*e*) Investigate approach and exit flow conditions, discharge characteristics of the structure, and characteristics of stratified flow over the weir proposed upstream of the powerhouse intakes. Tests were conducted on a 1:50-scale model that reproduced the entire spillway and 1800 ft of the approach and 2300 ft of the exit areas. The model allowed investigation of the stilling basin divider wall, water-quality weir, stilling basin, and riprap in the exit channel.
(*f*) Completed.
(*h*) **Spillway for Clarence Cannon Reservoir, Salt River, Missouri: Hydraulic Model Investigation,** *TR H-71-7,* Oct. 1971.

321-07158-350-13

MODEL STUDIES OF CLINTON AND FORT SCOTT OUTLET WORKS, WAKARUSA AND MARMATON RIVERS, KANSAS

(*b*) Kansas City District, Missouri River Division.
(*c*) E. S. Melsheimer, Structures Branch.
(*e*) Observe the hydraulic flow conditions in the outlet works conduits and verify the adequacy of the stilling basins and riprap requirements. Of particular concern was development of design criteria for outlet works stilling basins, where the outlet invert is submerged by tailwater, or where there is little drop from invert to tailwater. These conditions result in separation of flow at the sidewalls for small or intermediate discharges with resulting eddies and abrasive damage to the stilling basin. Tests were conducted on a 1:16-scale model which reproduced a schematic intake structure, the conduit, the outlet works stilling basin, and 800 ft of the exit channel. Tests were also conducted with a 1:5-scale model to ensure satisfactory flow conditions in a single low-flow conduit in the Fort Scott outlet works that will be used for selective withdrawal.
(*g*) Model tests indicated that separation of flow along the sidewalls and eddy action in the stilling basin could be eliminated or greatly reduced by limiting the sidewall flare to a maximum of 1 on 8. However, some eddy action in the basin is likely when the outlet invert is set at an elevation that allows tailwater to force the jump to the vicinity of the outlet at low and intermediate flows. Sloping the upstream face of the end sill in the stilling basin facilitates the removal of any material entering the basin. Tests on the low-flow outlet for Fort Scott revealed satisfactory flow conditions for all discharges with the control gate located within and perpendicular to the conduit. Unsatisfactory conditions were observed with the control gate at the entrance to the low-flow outlet.

321-07160-350-13

MODEL STUDY OF SPILLWAY, OAKLEY DAM, SANGAMON RIVER, ILLINOIS

(*b*) Chicago District, North Central Division.
(*c*) E. S. Melsheimer, Structures Branch.
(*e*) Determine the effect of reducing the elevation of the spillway from 628 to 621 and to develop the most desirable hydraulic features of the stilling basin. Also to be determined is the stability of the proposed riprap and the effect of the downstream highway embankment on the discharge characteristics of the spillway. Tests were conducted on a 1:60-scale general model that reproduced an approach area 2000 ft wide that extended upstream 1800 ft, the dam including the spillway and nonoverflow sections, and an exit area approximately 2000 by 1700 ft.
(*g*) Tests indicated that while the reduction in the height of the spillway from elevation 628 to 621 reduced the efficiency of the spillway it still permitted the maximum flow to be discharged within acceptable limits. The stilling basin was redesigned to permit satisfactory performance with the spillway reduced in elevation. Riprap protection selected for the higher spillway was found to be adequate with the spillway reduced 7 ft height. At expected tailwater depths, the presence of Rea Bridge and Road had no submergence effects on the spillway discharge until such discharge approached 110,000 cfs; above this discharge, a slight increase in the upper pool level was noted.

321-07163-410-13

MODEL STUDY OF BARNEGAT INLET, NEW JERSEY

(*b*) Philadelphia District, North Atlantic Division.
(*c*) R. A. Sager, Estuaries Branch.
(*e*) Evaluate the effectiveness of a proposed multiphase plan of improvement for Barnegat Inlet and feasible modifications to the plan for establishing a stable navigation channel through the inlet. Fixed- and movable-bed model tests were conducted to define the effects of the proposed plans of improvement on the hydraulic conditions and shoaling and scouring trends of the inlet, respectively.
(*f*) Tests complete. Report in progress.

321-07164-470-11

COMPARISON OF MATHEMATICAL AND HYDRAULIC MODELS FOR HARBOR OSCILLATIONS

(*b*) Coastal Engineering Research Center.
(*c*) Michael J. Mathews, Mathematical Hydraulics Branch.
(*e*) The project will compare the various mathematical models for harbor surge action with each other and with hydraulic models. Criteria for selecting among the mathematical models and hydraulic models will be presented and the best computer programs for Corps of Engineers use will be selected. The GE 430 and GE 600 computers will be used to verify the computer programs. Computer results will be compared with hydraulic model data derived from published literature and in-house model testing.
(*g*) Three of the four computer models have been successfully adapted and verified on the GE 400 or GE 600 computers. The fourth program (variable depth with radiating boundary) is adapted to the GE 600, but is not verified. An in-house modeling effort on the Port Hueneme Harbor will provide valuable comparison with physical models. Comparison with analytical closed-form solutions and available physical models has led to some conclusions on the utility of the computer programs. The Finite Element Method performs well in pinpointing resonant periods but yields no quantitative estimate of amplification. Lee's program

yields amplification estimates, but is restricted to uniform depth harbors and finds resonant periods by trial and error. Leendertse's computational method performs a time stepping calculation of wave heights and presents difficulties in describing the seaward boundary. The strengths of these three methods are being examined to develop a systematic computational plan of attack on a generalized problem.

321-07167-330-13

GRAYS HARBOR MODEL STUDY, WASHINGTON

(*b*) Seattle District, North Pacific Division.
(*c*) F. A. Herrmann, Estuaries Branch.
(*e*) Investigate the effects of reconstruction of the jetties at Grays Harbor entrance upon hydraulic conditions, salinity intrusion, flushing characteristics, and shoaling. To determine effects of realigned and improved navigation channels upon existing conditions. A combination fixed- and movable-bed hydraulic model (scale 1:500 horizontally and 1:100 vertically) including all of Grays Harbor, the Chehalis River to the head of tidal influence, and a suitable area of the Pacific Ocean adjacent to the harbor entrance is being used to reproduce tides, tidal currents, wave action, density currents, and freshwater inflow.
(*g*) Four studies have been completed to date and report drafts have been prepared.

321-07168-420-13

JAMAICA BAY HURRICANE BARRIER STUDY, NEW YORK

(*b*) New York District, North Atlantic Division.
(*c*) Thomas C. Hill, Estuaries Branch.
(*e*) Determine the effects of a hurricane protection structure with all tidal passages open on tidal heights, current velocities, salinities, temperatures, and dye dispersion within Jamaica Bay for normal tides. Plans which had no adverse effects on the above phenomena and which did not create maximum velocities hazardous to navigation were subjected to hurricane surges to determine the amount of suppression obtained throughout Jamaica Bay. An additional objective of the investigation to improve the quality of water in the bay has been added by the New York District. This modification may involve barrier gate operation and/or structural changes in the bay. The Jamaica Bay segment of the existing New York Harbor model was updated to topographic conditions of 1967. The existing New York Harbor model linear scale ratios are 1:100 vertically and 1:1000 horizontally. A hurricane surge generator was added to the model to conduct the surge test. A series of tests was conducted for existing conditions and then duplicated for plan conditions; comparison of test results allows the effects of the plans to be evaluated.

321-07169-330-13

SHOALING STUDIES OF 25-FT CHANNEL IN JAMES RIVER

(*b*) Norfolk District, North Atlantic Division.
(*c*) R. A. Boland, Jr., Estuaries Branch.
(*e*) To conduct tests involving plans to reduce shoaling in the existing 25-ft channel. Investigate dikes, spoil disposal areas, sediment traps, and channel realignments in an effort to reduce shoaling in the existing 25-ft channel.

321-07170-410-13

MODEL STUDY OF MORICHES INLET, N.Y.

(*b*) New York District, North Atlantic Division.
(*c*) R. A. Sager, Estuaries Branch.
(*e*) Develop an effective plan of improvement for Moriches Inlet to maintain a stable and safe navigation channel through the inlet and effectively transfer sand past the inlet. Fixed- and movable-bed model tests were conducted to define the effects of proposed plans of improvement on the hydraulic conditions and shoaling and scouring trends of the inlet, respectively.
(*g*) Several tests in both the fixed- and movable-bed models were conducted with various size navigation channels and single littoral traps at various locations or a combination of a littoral trap and rehandling basin each at various locations. Results indicated that a single littoral trap sufficiently protected from ocean waves to allow dredging to be effectively performed could not be considered. Previous tests with protective structures have been effective; however, excessive costs would be required. Tests conducted with the littoral trap located sufficiently landward to achieve wave protection demonstrated that material would not move into the littoral traps. Tests with a combination ocean littoral trap and interior rehandling basin indicated effective results could be achieved.

321-07171-470-13

INVESTIGATION OF SHOALING AT HARBOR ENTRANCES

(*b*) Vicksburg, Memphis, and New Orleans Districts, Lower Mississippi Valley Division.
(*c*) J. J. Franco, Waterways Branch.
(*e*) To develop methods of eliminating or reducing shoaling at entrances to harbors on the Mississippi River. The investigation is being conducted in an existing model modified for the study. The facilities include a channel about 12 ft wide and 200 ft long including two bends connected by a relatively long, straight reach with provision for constructing harbor entrances at various locations with respect to channel alignment. The study is of the movable-bed type with a crushed coal bed material.
(*g*) Designs for substantial reduction in shoaling in a harbor entrance on the outside of a bend, on the inside of a bend, and in a straight reach have been developed for one channel alignment.

321-07172-400-13

MODEL STUDY OF SHREWSBURY RIVER, NEW JERSEY

(*b*) New York District, North Atlantic Division.
(*c*) Thomas C. Hill, Estuaries Branch.
(*e*) To determine the effects of a small-boat channel across Sandy Hook peninsula on tides, current velocities, salinities, shoaling, dye dispersion, hurricane surge elevations, and temperatures within Sandy Hook Bay and the Shrewsbury and Navesink Rivers. The Sandy Hook Bay was updated to topographic conditions of 1968 and the Shrewsbury and Navesink Rivers were added to the existing New York Harbor model. Linear scale ratios for the model are 1:100 vertically and 1:1000 horizontally. A series of model tests were conducted for existing conditions and duplicated with the inlet installed; comparison of test results indicates the effects of the inlet on related phenomena.
(*g*) All proposed model tests have been completed and a summary report has been prepared.

321-07173-330-13

NAVIGATION CONDITIONS AND DEVELOPMENT OF FILLING AND EMPTYING SYSTEM AT BANKHEAD LOCK, BLACK WARRIOR RIVER, ALABAMA

(*b*) Mobile District, South Atlantic Division.
(*c*) N. R. Oswalt, Structures Branch.
(*e*) Determine the optimum location for a new 670-ft-long by 110-ft-wide lock with a 69-ft lift at Bankhead with respect to the existing dam and to test surges in the upstream approach canal to the lock. A 1:100-scale model of a 3-mile reach of the Black Warrior River including the existing powerhouse, dam, and locks was constructed to simulate river navigation conditions. Hydraulic navigation conditions and excavation plans were used to compare proposed new lock locations. Model surges were investigated in the upstream lock approach and canal during lock filling operations. A computerized mathematical model was also used in investigations to minimize surge problems. A 1:25-scale model of the entire filling and emptying system was constructed to develop the optimum longitudinal floor culvert arrangement.

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(*f*) Tests complete. Report in progress.
(*g*) The major purpose of the general model testing was accomplished by determining hydraulic aspects of lock site selection. With the adopted downstream cofferdam in place, navigation conditions will be difficult, but will not be any more difficult than they are under present conditions. Maximum surge due to lockage, the effect of a second lockage on maximum surges, the effect of the surge on moored tows, and the maximum reverse head on the upstream gate due to surge and lock filling overtravel were determined and can be minimized by allowances in design. A longitudinal floor culvert filling and emptying system which results in excellent performance was developed in the lock model. With the culvert valves opened 1 min, at the normal lift of 69 ft, the lock model is filled in 9.2 min or emptied in 11.0 min. Due to differences in friction losses the prototype lock can be expected to fill and empty in 0.5 to 1.0 min faster than the model. Deflector piers in the wall culverts near the center of the locks were required to obtain satisfactory pressure conditions on the noses of piers which divide filling flows between the two halves of the lock chamber and to stabilize pressures at and downstream from the flow bifurcation. Preparation of the final report is in progress.

321-07174-330-13

LOCK PROTOTYPE TESTS, BARKLEY LOCK, CUMBERLAND RIVER, KENTUCKY

(*b*) Nashville District, Ohio River Division.
(*c*) F. M. Nelson, Hydraulic Analysis Branch, Hydraulics Division.
(*e*) To measure hawser forces, lock water-surface elevations and slopes, average and fluctuating pressures, valve performance, and auxiliary measurements. The effects of valve speed, single and nonsynchronous valve operation, overfilling, and air venting on hawser forces, valve and culvert pressure fluctuations, valve hoist loads, and vibrations were measured. Data measurements of pressure, strain displacement, acceleration, etc., from 49 transducers were recorded on oscillograph records and nine on analog magnetic tape during 27 filling and 6 emptying operations. Fourteen runs were made with a tow moored in the lock in order to obtain hawser forces and tow motion data. Data reduction is by means of scaling oscillograph and magnetic tape records and comparing results with theory, design practice, and model study results.
(*f*) Final report in progress.

321-07176-330-13

MODEL STUDY OF DEVIL'S ISLAND REACH, MISSISSIPPI RIVER

(*b*) St. Louis District, Lower Mississippi Valley Division.
(*e*) Development of the most economical and effective plan of regulating structures that would provide a channel of adequate depth and alignment for navigation without excessive maintenance. A movable-bed model with scales of 1:400 horizontally and 1:100 vertically reproducing the reach of the Mississippi River between miles 55 and 68 and the adjacent overbank areas was used.
(*f*) Tests complete. Final report in progress.

321-07177-300-13

INVESTIGATION OF DIKE DESIGN

(*b*) Vicksburg, Memphis, New Orleans, and Lower Mississippi Valley Division.
(*c*) J. J. Franco, Waterways Branch.
(*e*) Determine the factors affecting the performance of dikes and dike systems to provide indications as to the relative effectiveness of the various factors and provide a basis for the development of principles for use in the design of dikes. The investigation is being conducted in a 40-ft-wide by 200-ft-long by 1.5-ft-deep flume which provides flexibility for the development of various types of river problems. The study is of the movable-bed type with a crushed coal bed material.
(*g*) The study has indicated the effects of various changes in design parameters but has not progressed to the point that these effects can be considered conclusive.

321-07179-420-13

FLUME TESTS FOR TSUNAMI STUDY, CRESCENT CITY, CALIFORNIA

(*b*) San Francisco District, South Pacific Division.
(*c*) Paul Senter, Wave Dynamics Branch.
(*e*) A preliminary plan has been proposed for construction of an earth-filled barrier across existing tidal beaches and terminating at high land east and west of Crescent City to protect the city from the devastating effects of tsunami waves. The objective of this study was to determine design parameters for a three-dimensional model of Crescent City, Calif., which would be used to develop an optimum design for the proposed tsunami barrier, and to approximate the effect on runup elevation that would be reached with a barrier in place to provide a basis for preliminary reevaluation of the plan to determine advisability of continuing the investigation. Tests were conducted in a 2-ft-wide flume to aid in designing a three-dimensional tsunami model of Crescent City Harbor, Calif. The three-dimensional model will be used to investigate the technical feasibility of a levee-type barrier to protect the city from attack by tsunamis. The present investigation was conducted to determine (a) how runup of tsunami waves is affected by model-scale distortion and change in wave period and (b) an approximate crown elevation needed to prevent all but minor overtopping of the barrier by tsunami waves. This information was needed to allow preparation of a preliminary estimate of the cost of the proposed barrier.
(*f*) Completed.
(*h*) **Design of Proposed Crescent City Harbor, California, Tsunami Model: Hydraulic Model Investigation,** *TR H-71-2*, Feb. 1971.

321-07180-430-13

MODEL STUDY OF FLOATING BREAKWATER, OAK HARBOR, WASHINGTON

(*b*) Seattle District, North Pacific Division.
(*c*) R. W. Whalin, Wave Dynamics Branch.
(*e*) To determine the effectiveness of the proposed structure in reducing the existing wave heights; the mooring forces for both chain and pile mooring systems for the existing wave conditions; whether oscillations of the proposed structures would be resonant within the range of existing wave conditions; and the natural period of proposed breakwater module unrestrained in still water. A two-dimensional model study was conducted in the WES 119-ft-long, 5-ft-wide, 4-ft-deep wave flume. A model scale of 1:10 was used for the study in which only one unit of the prototype structue, -2 by 10 by 7 ft, was reproduced geometrically and dynamically. A flat bottom flume was used since most of the wave conditions tested are deep-water waves. Model waves were generated by a vertical-displacement type plunger connected to a variable-speed drive mechanism, and were measured and recorded electrically.
(*f*) Completed.
(*h*) **Wave Transmission and Mooring Force Tests of Floating Breakwater, Oak Harbor, Washington: Hydraulic Model Investigation,** *H-71-3*, April 1971.

321-08623-060-00

MECHANICS OF FLOW IN STRATIFIED RESERVOIRS

(*b*) Office, Chief of Engineers.
(*c*) J. L. Grace, Jr.
(*e*) To study and develop means of describing the mechanics of stratified flow into, within, and from stratified reservoirs including the effects of releases through orifices and over weirs. These data are vitally needed for prediction of the quality of impounded water, design of selective withdrawal structures, and effective management of local and regional

water resources. Experimental flumes at scales of 1:5 to 1:100 are used to simulate general and specific reservoirs and appropriate structures. Temperature and conductivity probes are used to quantify salt-induced density gradients, while photographic methods are employed to measure velocity profiles. See also No. 6846 in past issues.

(*h*) **Selective Withdrawal Characteristics of Weirs,** *TR H-71-4*, June 1971.

321-08624-360-10

STILLING BASIN SIDEWALL PRESSURE FLUCTUATIONS

(*b*) Office, Chief of Engineers.
(*c*) B. P. Fletcher.
(*e*) Investigate instantaneous forces generated by a hydraulic jump acting in monoliths composing a stilling basin wall. Variables to be investigated include Froude number, discharge, tail-water elevation, and monolith position, height, and width. Model tests are conducted in a 6-ft-wide and 20-ft-long approach channel to a 2.5-ft-long spillway crest. The stilling basin is 9 ft long and the stilling basin sidewall consists of seven monoliths of machined aluminum. Tests are conducted to determine the magnitude and frequency of the forces generated by the hydraulic jump acting on the stilling basin monoliths.

321-08625-330-10

EFFECT OF TOW AND SHIP SIZE ON LOCKAGE TIME

(*b*) Office, Chief of Engineers.
(*c*) Noel R. Oswalt.
(*e*) Provide information on the effect of tow and ship size on transit time for entering and departing locks in order to provide a basis for establishing regulations on maximum sizes of tows and ships that will be permitted to use particular locks. No facilities are available for testing; and until adequate funding is provided, no model work other than design of a facility can be accomplished. A facility 110 ft wide by 670 or 1270 ft long is considered desirable with a modern operable filling and emptying system and appropriate approach and exit areas and appurtenances. The tow and ships would either be self-propelling and radio-controlled or mechanically operated to simulate present as well as new methods to optimize as well as provide safe transit time at navigation locks.
(*g*) The literature search was completed. Model sketches and a general outline of procedure to be followed for model testing were formulated. A model scale of 1:36 has been established and purchase of measuring equipment and beginning construction of facility are scheduled for early 1972 as funding permits.

321-08626-310-13

MODEL STUDY OF SOUTH ELLENVILLE FLOOD CONTROL PROJECT, NEW YORK

(*b*) New York District, North Atlantic Division.
(*c*) E. S. Melsheimer, Structures Branch.
(*e*) Determine the hydraulic and structural adequacy of the design and to refine the design of various elements of the project as necessary. To investigate flow conditions in the high-velocity chute and stilling basin of the project. Of particular interest will be the disturbance effect of large boulders in the chute, the effects of increased disturbances due to proximity of the bends to each other, and the effect of bends on free-board requirements. Erosion characteristics below the stilling basin are also to be determined. Tests were conducted in a 1:20-scale model that reproduces about 200 ft of the approach to the high-velocity chute, the entire chute, the stilling basin, and approximately 600 ft of Sandburg Creek at the channel junction.

321-08627-000-14

FREE SURFACE VORTEX RESEARCH

(*b*) Army, Research Office, Durham.
(*c*) Dr. G. H. Keulegan.
(*e*) Provide basic laboratory information concerning the effects of fluid viscosity on (a) the incipient conditions for vortex formation, (b) its shape and size, and (c) its rate of decay; and to compare experimental results with theory and other laboratory information in an effort to improve the understanding of the vortex phenomenon. The following variables will be considered in a systematic laboratory investigation of the free surface vortex in a cylindrical tank; radius of tank, diameter of orifice, depth of fluid in tank, radial and tangential velocity, kinematic viscosity of fluid, density of fluid, surface tension of fluid, acceleration of gravity, depression of surface at particular distance from center of tank, and circulation. Observations will be made of incipient conditions for vortex formation with each fluid. Surface and velocity measurements will be made during stable flow conditions.
(*g*) Experimental work has been completed. Analysis of the data was completed. Preliminary analysis indicated a definite effect of viscosity, circulation, and depth of flow on the formation of an air core and the efficiency of the outlet. Conditions of air core formation appear to be predictable for the outlet studied. No evidence of surface tension effects has been found.

321-08628-700-10

INTEGRATED DENSITY PROBE DEPTH SOUNDING SYSTEM

(*b*) Office, Chief of Engineers.
(*c*) J. J. Franco.
(*e*) Develop an integrated system consisting of a depth sounder and a remote density sensor which together will indicate a deposition of sediment, both depth and density, that would interfere with navigation and require dredging. The characteristics of lightweight sediments will be determined and equipment which will identify the density signature of the sediments will be developed.
(*g*) A survey of the available literature on the subject and contacts with District offices to determine current practices, problems encountered, and suggestions for improvement in survey and dredging operations have been accomplished.

321-08629-410-10

SAND BYPASSING METHODS

(*b*) Office, Chief of Engineers.
(*c*) Richard A. Sager.
(*e*) Develop effective systems for bypassing sand at tidal inlets and other obstructions to littoral transport, including dredged channels, entrance jetties with and without weir sections and sand traps, and breakwaters. A detailed state-of-the-art determination will initiate the study with laboratory and field investigations conducted as dictated by the state-of-the-art. The study will include both equipment evaluation and effectiveness of structures.
(*g*) Several sand bypassing methods that have been proposed or tried have been identified. An inventory of existing eductor equipment has been partially completed. Identification of potential contractors for field investigations has been initiated and detailed plans for laboratory tests have been initiated. Possible sites for field tests are being evaluated.

321-08630-330-13

ANALYTICAL STUDY OF SALINITY INTRUSION IN THE CHESAPEAKE AND DELAWARE CANAL

(*b*) Philadelphia District, North Atlantic Division.
(*c*) Carl J. Huval, Hydraulics Division.
(*e*) Determine the effect of the channel enlargement project on salinity conditions in the canal and the changes caused by the channel enlargement. Analytical estuarine relations and mathematical models were utilized. These relations are being applied to the salinity conditions in the Chesapeake and Delaware Canal. Computer programs are being developed for solution of the equations.
(*g*) The study was initiated with a review of the analytical solutions to the convective-dispersion equation governing

the salinity distribution in a one-dimensional channel. An explicit, finite difference method of solution was devised and programmed on the computer. Several solutions were obtained for constant net channel flows, dispersion coefficients, and boundary salinity conditions. The numerical solutions compared favorable with known analytical solutions. A study was made of dispersion coefficients in estuarine flows. A method of incorporating variable salinity boundary conditions and variable canal velocities was developed to better simulate the intratidal salinity distributions. The investigation has been completed, and preparation of the final report is in progress.

321-08631-330-13

CHESAPEAKE AND DELAWARE CANAL STUDY

(*b*) Philadelphia District, North Atlantic Division.
(*c*) Thomas C. Hill, Estuaries Branch.
(*e*) The Chesapeake and Delaware Canal, which serves as a navigation connection between Chesapeake Bay and Delaware River, is being enlarged from a 250-ft-wide by 27-ft-deep canal to a 450-ft-wide by 35-ft-deep canal. It was desired to know the effects of this enlargement on tides, current velocities, salinities, and net discharge for various mean tide level conditions. The Chesapeake and Delaware Canal and Elk River were added to the existing comprehensive fixed-bed Delaware River model. The linear scales of the model are 1:100 vertically and 1:1000 horizontally. The model has methods for reproducing tides, tidal currents, salinities, and freshwater inflows. Tests were conducted for base or existing conditions and for plan conditions. Comparisons of results of the two tests allows one to determine the effects of the plan on related phenomena.
(*f*) Tests completed. Final report in progress.

321-08632-750-10

POSTCONSTRUCTION VERIFICATION OF PHYSICAL MODEL PREDICTIONS

(*b*) Office, Chief of Engineers.
(*c*) G. M. Fisackerly.
(*e*) Define the confidence limits which can be placed on the prediction of ecologically important parameters affected by modifications to estuary systems and will thus aid in bringing the knowledge and experience of ecologists to bear on the planning processes. Initial effort would consist of selecting an estuary for study and planning and coordinating field surveys. It is intended that the proposed studies establish the degree of confidence in the results of sedimentation studies and enhance the degree of confidence already established for the prediction of tide heights and phases, current velocities and directions, and salinity concentrations.
(*g*) Fifteen slected data collection stations located throughout the Philadelphia to Trenton reach of the Delaware River have been monitored. Salinity concentrations, current velocities, and current directions at three depths (surface, middepth, and bottom) were obtained at each station. Tide heights and freshwater inflows have been monitored by the Philadelphia District and the data obtained will be forwarded to this office. No conclusions can be drawn at this time and no reports are available.

321-08633-330-13

MATHEMATICAL MODELING OF FLOW CONDITIONS IN CHESAPEAKE AND DELAWARE CANAL

(*b*) Philadelphia District, North Atlantic Division.
(*c*) Marden B. Boyd, Mathematical Hydraulics Branch.
(*e*) Determine the effect of the channel enlargement project on flow conditions in the canal. The study utilized existing computer programs to investigate flow conditions in the Chesapeake and Delaware Canal. The programs use an explicit finite difference solution scheme to solve the one-dimensional unsteady-flow equations. Computations were made for the 27-ft channel that existed prior to the present enlargement project and for the completed 35-ft channel.
(*g*) Flow conditions were computed for the original canal and for the cnlarged canal assuming a constant density fluid throughout the canal. Computation results showed that second order magnitude changes in head differential through the canal caused large changes in net flow through the canal. It thus appears that the effect of differences in average salinity at the ends of the canal on effective head differential must be considered to obtain the most accurate estimates of net flow through the canal. The investigation has been completed, and preparation of the final report is in progress.

321-08634-870-10

EFFECTIVENESS OF PHYSICAL MODELING OF HEAT DISPERSION IN ESTUARIES

(*b*) Office, Chief of Engineers.
(*c*) M. J. Trawle.
(*e*) Verify that physical models of various types of estuaries constructed to several distorted-scale ratios are capable of reproducing the far-field dispersion and deterioration characteristics of thermal waste in estuaries. Field measurements will be made at selected power generating plants, power plant operation will be simulated in existing physical models, and comparable measurements will be made.
(*g*) An analytical study and literature review has been completed. The organization of the remote sensing and ground truth prototype data collection program and preparation for model testing have been initiated.

321-08635-740-10

MATHEMATICAL MODELS IN ANALYTICAL AND EXPERIMENTAL HYDRAULICS

(*b*) Office, Chief of Engineers.
(*c*) C. J. Huval.
(*e*) Conduct research and develop utilization of new, high-level, computer-based mathematical modeling and data handling techniques for hydraulic problems to be used in conjunction with and, in some cases, to replace hydraulic models. This project is envisioned as a long-range, continuing effort to supplement and improve mathematical models and computerized data handling. The approach and model methodology will be strongly dependent on the field design problems.
(*g*) Work under this investigation was concentrated in the area of development of mathematical models for estuaries. A study of past and current literature has been made on various mathematical models previously developed for use in estuarine design. Work was continued on mathematical model development of one-dimensional salinity distributions for well-mixed estuaries. Work was completed on applications and extensions of Keulegan's lumped parameter approach to predict bay water heights and velocities in tidal inlets. A generalized numerical computational model to solve the nonlinear differential tidal hydraulic equations has been developed and programmed for the digital computer. The methodology includes the inertia effects, variable bay surface area, variable depth in the inlet, and mixed ocean tide. A method to compute an equivalent prismatic inlet for variable area inlet channels has been developed.
(*h*) **Predicting Construction Effects by Tidal Modeling,** *WES MP H-71-6.*

321-08636-860-10

METHODS OF ENHANCING WATER QUALITY

(*b*) Office, Chief of Engineers.
(*c*) Joseph P. Bohan.
(*e*) Study methods and feasibility of mixing water in lakes and rivers as a means of enhancing water quality. Hydraulic models will be used to study the effectiveness of various techniques for mixing a density stratified reservoir. The effects of reservoir geometry on mixing will be studied as

well as the optimum placing of mixing devices in a reservoir.

(*g*) Plans have been made and tests will commence shortly in an existing facility to obtain some preliminary information regarding mixing with air bubble devices and by pumping water from the bottom of a reservoir and discharging it at the surface.

321-08637-420-13

WATER WAVES GENERATED BY LANDSLIDES, LIBBY RESERVOIR, MONTANA

(*b*) Seattle District, North Pacific Division.
(*c*) R. W. Whalin, Wave Dynamics Branch.
(*e*) Determine the magnitude of wave heights, runup, overtopping of the dam, and wave pressures on the powerhouse if overtopping of the dam occurs for the expected landslides. A three-dimensional model is being constructed at an undistorted scale of 1:120. The entire model area is approximately 2300 sq ft, which reproduces the dam and the reservoir topography for about one mile upstream of the dam and about 1200 ft downstream of the dam. The overbank of the model is reproduced to elevation 2700 msl and a mechanical slide machanism will provide support for landslides above elevation 2700. There are three main potential landslide areas in the reservoir, located approximately 700, 1400, and 2100 ft upstream of the dam and containing potential volumes from 1.6 to 4.9 million cu yd of material. These slides will be reproduced by sliding small bags of rubble iron ore into the model at various speeds. The resulting wave data will then be measured at various locations over the reservoir.

321-08638-060-10

MECHANICS OF DENSITY STRATIFIED FLOW IN LAKES AND RIVERS

(*b*) Office, Chief of Engineers.
(*c*) Joseph P. Bohan.
(*e*) Study the basic mechanics of density stratified flows so that more accurate techniques can be developed to predict the movement of density currents into, through, and from an impoundment as well as in streams. A physical model simulation of geometric, hydrologic, and meteorologic factors will be used to investigate steady and unsteady flow conditions in a reservoir system.
(*g*) A portion of the facility design has been accomplished and supplies for the construction of the model have been ordered along with some of the required instrumentation. Conceptual plans have been formulated for the overall project and detailed planning remains.

321-08639-860-10

PREDICTION AND CONTROL OF WATER QUALITY IN LAKES AND RIVERS

(*b*) Office, Chief of Engineers.
(*c*) Joseph P. Bohan.
(*e*) Develop means of predicting the thermal, chemical, and biological quality of water in lakes and rivers. A literature review will be conducted and various existing techniques evaluated to determine their adequacy. A model will then be developed based on existing knowledge in such a way that future improvements in the state-of-the-art can be easily incorporated.
(*g*) A review of several existing mathematical models for reservoir temperature prediction has been conducted and source decks have been requested. Two programs have been adapted for use on the computer available to WES and another program is being incorporated in the time-sharing system.

321-08640-360-13

STILLING BASIN FOR SPILLWAY AT LOCKS AND DAM NO. 26 (REPLACEMENT), MISSISSIPPI RIVER

(*b*) St. Louis District, Lower Mississippi Valley Division.
(*c*) Noel R. Oswalt, Structures Branch.
(*e*) Determine the optimum stilling basin and riprap design for new Locks and Dam No. 26 (Replacement). A new dam with two 1200- by 110-ft locks is planned for construction near Alton, Ill., to replace the existing obsolete structure. The two locks, on the Illinois side of the river, will be separated by two 110-ft-wide spillway bays with eight additional 110-ft-wide bays connecting to the Missouri bank. A 1:36-scale model reproduces the eight spillway bays, 500 ft of upstream topography, and 1500 ft of downstream topography. A temporary wall permits study of flows through the two spillway bays between the locks.
(*f*) Report in progress.

321-08641-350-13

TAINTER GATE MODEL, LOCKS AND DAM NO. 26 (REPLACEMENT), MISSISSIPPI RIVER

(*b*) St. Louis District, Lower Mississippi Valley Division.
(*c*) Noel R. Oswalt, Structures Branch.
(*e*) Determine if gate vibrations occur for the proposed structure within the range of operating conditions. A 1:24-scale model that reproduces one full gate bay with the gate members and shape accurately reproduced, the two adjacent half bays with schematic gates, the spillway crest, two crest piers, and the stilling basin in a 12-ft-wide flume is being used for the study.
(*f*) Report in progress.

321-08642-350-13

MODEL STUDY OF TROTTERS SHOALS DAM AND RESERVOIR, SAVANNAH RIVER, GEORGIA

(*b*) Savannah District, South Atlantic Division.
(*c*) Bobby P. Fletcher, Structures Branch.
(*e*) Investigate approach and exit flow conditions, discharge characteristics of the spillway, surging on tainter gates, operation of the flip bucket, and the lip angle of the bucket. Tests were conducted with a 1:80-scale model that reproduced the structure and sufficient area of the approach and exit channels. The model permitted investigations of characteristics of flow over the spillway, performance of various energy dissipators, and forces acting on the stilling basin wall.

321-08643-350-13

WARM SPRINGS DAM OUTLET WORKS, DRY CREEK, RUSSIAN RIVER, SONOMA COUNTY, CALIFORNIA

(*b*) San Francisco District, South Pacific Division.
(*c*) J. H. Ables, Jr., Structures Branch.
(*e*) Study the effect of the conduit curve on performance of the stilling basin, particularly when the conduit is flowing partially full. Also, it is desired to verify the adequacy of the alignment of the conduit and of the riprap in the exit channel. A 1:25-scale model was constructed and reproduces the gated control structure, approximately 2500 ft of conduit and appropriate transitions, a primary and seondary stilling basin with a fish barrier dividing the two basins, and 1400 ft of exit channel.

321-08644-330-13

MODEL STUDY OF ENTRANCE TO UPSTREAM APPROACH CANAL, GAINESVILLE LOCK, TENNESSEE-TOMBIGBEE WATERWAY

(*b*) Mobile District, South Atlantic Division.
(*c*) J. J. Franco, Waterways Branch.
(*e*) Investigate navigation conditions near the entrance to the proposed bypass canal and in the short radius bends upstream of the canal entrance, to investigate flow over the spillway, and to develop modifications considered desirable. Tests will determine size and shape of the upstream entrance to the canal and the minimum channel width required in the short bend upstream of the canal to provide satisfactory navigation conditions.

321-08645-330-10

MODEL STUDY OF GALLIPOLIS LOCKS AND DAM, OHIO RIVER

(*b*) Huntington District, Ohio River Division.
(*c*) J. J. Franco, Waterways Branch.
(*e*) Develop satisfactory navigation conditions at the existing site and at a new site, and to develop information that could be used to evaluate the relative merits of the two proposals. Tests were conducted to determine the best arrangements of lock guard and guide walls and improvements in the lock approaches required to permit maximum usage of both locks, and to determine the best location for lock filling and emptying culverts to minimize adverse effects on navigation moving in the lock approaches.

321-08646-330-13

ANALYTICAL SURGE STUDY–CHICAGO SANITARY AND SHIP CANAL

(*b*) Chicago District, North Central Division.
(*c*) Marden B. Boyd, Mathematical Hydraulics Branch.
(*e*) Conduct an analytical study of surges resulting from operation of the proposed 1200-ft lock at Lockport on the Illinois Waterway. The study is being accomplished utilizing existing computer programs which use an explicit finite difference solution scheme to solve the one-dimensional unsteady flow equations.
(*g*) Results of the initial computations for a 39-ft lift indicated that objectionable surges may result from filling and emptying operations at the proposed new lock. More refined computations have been made in the immediate area of the lock to evaluate the effect of changes in channel dimensions and to investigate the need for surge basins. Opening of the area in the upstream approach between the old lock and the proposed new lock eliminates any serious problem upstream of Lockport. Computations indicate that some additional excavation or a surge basin is needed in the downstream approach to alleviate objectionable surging.

321-08647-400-13

TILLAMOOK BAY, OREGON, MODEL STUDY

(*b*) Portland District, North Pacific Division.
(*c*) George M. Fisackerly, Estuaries Branch.
(*e*) Determine the effects on the regimen of the bay of various combinations of jetty spacing and channel dimensions. A fixed-bed model of Tillamook Bay was constructed in its entirety and included a suitable area of the Pacific Ocean. Provisions were made to reproduce tides, currents, salinity intrusion, and freshwater discharge. Linear scales of the model were 1:500 horizontally and 1:100 vertically.
(*f*) Tests completed. Report in preparation.

321-08648-470-13

MODEL STUDY OF HAMLIN BEACH HARBOR, NEW YORK

(*b*) Buffalo District, North Central Division.
(*c*) R. W. Whalin, Wave Dynamics Branch.
(*e*) Determine the optimum design of the proposed harbor. A 1:64-scale model of the proposed harbor and sufficient portion of Lake Ontario needed to generate the required test waves will be used to determine the optimum design of the harbor.

321-08649-470-13

MODEL STUDY OF PORT HUENEME, CALIFORNIA

(*b*) Los Angeles District, South Pacific Division.
(*c*) R. W. Whalin, Wave Dynamics Branch.
(*e*) Determine what effects the new construction will have on long-period surge in the harbor. A 1:100-scale model of the harbor and sufficient ocean area to permit generation of the required test waves will be used to study the effects of the new construction on long-period surge. The results of the hydraulic model will be compared with various mathematical models.

321-08650-410-13

MODEL STUDIES OF PERCHED BEACH, SANTA MONICA BAY, CALIFORNIA

(*b*) Los Angeles District, South Pacific Division.
(*c*) R. W. Whalin, Wave Dynamics Branch.
(*e*) To aid in determining the technical feasibility and optimum design factors of the perched beach concept. An undistorted two-dimensional model (scale 1:30) was used to determine the structural design of the submerged toe structure for various depths. A distorted-scale, two-dimensional, movable-bed model was used to determine an estimate of the amount of sand that would be lost seaward over the toe structure by normal and storm-wave action, the optimum crown elevation of the structure, and the length of a stone blanket required to reduce seaward migration of sand to a minimum. An undistorted three-dimensional fixed-bed model (scale 1:100) was used to determine the effect of the perched beach on rip currents.
(*f*) Tests complete; report in progress.

U.S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, CRYOGENICS DIVISION, INSTITUTE FOR BASIC STANDARDS, Boulder, Colo. 80302. Dudley B. Chelton, Division Chief.

322-07003-230-50

CAVITATION SIMILARITY STUDIES

(*b*) National Aeronautics and Space Administration, Lewis Research Center.
(*c*) Mr. Jesse Hord, Mechanical Engineer.
(*d*) Experimental and theoretical; basic and applied research.
(*e*) Extend the capability to design and predict the performance of liquid pumps and other liquid-handling components. The experimental program requires testing of five hydrodynamic bodies in liquid hydrogen and liquid nitrogen; desinent, incipient, and developed cavitation data are acquired. The data are then analyzed and correlation techniques are developed to account for scale size, geometry, fluid, fluid velocity, fluid temperature, etc.
(*g*) Experiments are completed. Data analysis, correlation, and extensions of cavitation-performance predictive techniques are in progress.
(*h*) **Cavitation in Liquid Cryogens,** D. K. Edmonds, J. Hord, in *Advances in Cryogenic Engineering* **14,** pp. 274-282, Plenum Press, N.Y.
Experimental Studies on Thermodynamic Effects of Developed Cavitation, (discussion of paper by R. S. Ruggeri) J. Hord, *Proc. Intl. Symp. Fluid Mechanics and Design of Turbomachinery*, Penn. State Univ., Sept. 1970. NASA special publication–to be published.
Tabulated Values of Cavitation B-Factor for Helium, H_2, N_2, F_2, O_2, Refrigerant 114, and H_2O, J. Hord, R. O. Voth, *NBS Tech. Note 397*, Feb. 1971.
Cavitation in Liquid Cryogens, Volume I: Venturi, J. Hord, L. M. Anderson, W. J. Hall, NASA Contractor Report, 1971.

322-07005-110-00

CRYOGENIC FLOWMETERING

(*b*) Joint NBS-Compressed Gas Association Program.
(*c*) Mr. J. A. Brennan, Mechanical Engineer.
(*d*) Experimental; applied research.
(*e*) Determine performance of existing classical flow measurement devices under controlled cryogenic conditions; establish methodology for the use of these devices in cryogenic service; investigate new flow measurement methods.

(*g*) The facility is presently operational and is being used to evaluate measurement devices such as turbine, momentum, vortex shedding, and orifice meters.

(*h*) **Cryogenic Flowmetering Research at NBS,** D. B. Mann, *Cryogenics* **11,** 3, June 1971.
An Evaluation of Positive Displacement Cryogenic Volumetric Flowmeters, J. A. Brennan, J. W. Dean, D. B. Mann, C. H. Kneebone, *NBS Tech. Note 605*, July 1971.
Cryogenic Flow Research Facility Provisional Accuracy Statement, J. W. Dean, J. A. Brennan, D. B. Mann, C. H. Kneebone, *NBS Tech. Note 606*, July 1971.

322-07007-130-00

CRITICAL (CHOKING) TWO-PHASE FLOW

(*b*) Joint NBS-UKAERE, Harwell, England.
(*c*) Mr. D. B. Chelton, Division Chief.
(*d*) Theoretical and experimental; Doctoral thesis.
(*e*) Theoretical and experimental work was done to produce predictive expressions for two-phase, critical flow.
(*f*) Suspended.
(*g*) Results indicate that a theoretical model is successful for cases where the flow of the phases is characteristically separated and that choking or critical flow occurs essentially in the gas phase. This information is required for optimal design of a wide range of systems in power generation, petroleum and cryogenics.
(*h*) **Steam-Water, Critical Flow in a Venturi,** R. V. Smith, *NBS Tech. Note No. 608*, July 1971.
Two-Phase, Two-Component Critical Flow in a Venturi, R. V. Smith, *ASME Paper No. 71-FE-4*, May 1971 (to be published in ASME Trans., J. Basic Engineering).

U.S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, MECHANICS DIVISION, INSTITUTE FOR BASIC STANDARDS, FLUID METERS SECTION, Washington, D. C. 20234. Fillmer W. Ruegg, Section Chief.

323-07242-700-22

AUTOMATED FLOW SYSTEMS

(*b*) Naval Air Systems Command.
(*c*) Dr. David W. Baker, Research Engineer, NBS.
(*d*) Experimental; development.
(*e*) Methods and equipment for automatic testing and calibration of aircraft fuel system components are being investigated. At present, during the adjustment and calibration of gas turbine engine fuel controls, an operator manually sets input test parameters which remain stationary during a short time interval when test output data are manually recorded. Adjustments are made on the fuel control under test to bring the performance within specified limits. In this program, the control of input parameters, compressor discharge pressure and test stand rpm, and the readout of control discharge flow rate, the test output, have been automated, and the use of computer programmed diagnostic aids for the adjustment process are being studied. Emphasis is being placed on application of minicomputer equipment, and on digital-oriented control and readout equipment automating a conventional fuel control test stand installed at NBS. Earlier work with this prototype equipment indicates systems employing such digital equipment are technically feasible, and present objectives include evaluating the effectiveness of diagnostic aids which predict adjustments based on current performance.
(*g*) Software programs implementing operation of these prototype systems and calibration tests for one model fuel control are complete. Initial programs, based on diagnostic procedures devised by Bendix Corporation, and accompanying experiments indicate adjustments can be predicted, which effectively save operator test time and effort. Thus, both automated operation and diagnostics are expected to contribute to significant economies in test time.
(*h*) **A Prototype System for Automated Control of a PWA Fuel Control Test Stand,** D. W. Baker, A. L. Koenig, C. T. Collett, *NBS Report 10566*, April 1971.

U.S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, MECHANICS DIVISION, INSTITUTE FOR BASIC STANDARDS, HYDRAULICS SECTION, Washington, D.C. 20234. Dr. G. Kulin, Section Chief.

324-05613-060-20

RESPONSE OF A DENSITY-STRATIFIED LIQUID TO A SOURCE OR SINK IMPULSE

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Mr. Karl Lofquist, Physicist.
(*d*) Theoretical and experimental; basic research.
(*e*) A study of the internal waves produced by the sudden efflux or influx of liquid through a foam rubber hollow sphere simulating a "source" or "sink" situated within a linearly stratified liquid.
(*f*) Report in progress.

324-07243-060-20

MEASUREMENT OF LEE WAVE DRAG ON SPHERES

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Mr. Karl Lofquist, Physicist.
(*d*) Experimental and theoretical; basic research.
(*e*) Measurement of difference in drag between sphere moving in linearly stratified salt water and in fresh water.
(*f*) Experiments in progress.

324-07824-410-11

SAND TRANSPORT BY WAVES

(*b*) Coastal Engineering Research Center.
(*c*) Mr. Karl Lofquist, Physicist.
(*d*) Experimental and theoretical; basic research.
(*e*) Investigation of the effect of seepage flows, caused by passage of waves over a permeable bed, on the sand transport in the offshore zone.
(*g*) An apparatus is under construction which will simulate wave-induced motion by piston-actuated flows oscillating sinusoidally over sand beds in closed rectangular channels. Two identical adjacent channels are used, connecting only through the sand bed. Each channel has its own piston to produce identical oscillating flows, but a separate set of pistons superposes small seepage flows between the two channels. Sediment transport in the two channels, which will differ only by virtue of the seepage flow, will be observed by collecting sand in traps over many wave cycles.

324-08651-170-20

MIXING EFFECT OF RAINDROP IMPINGEMENT ON A WATER SURFACE

(*b*) Office of Naval Research, Dept. of the Navy.
(*c*) Mr. James Potzick, Physicist.
(*d*) Experimental; basic.
(*e*) To study the fluid motions associated with raindrop impact, with emphasis on investigating conditions leading to the formation of subsurface ring vortices.
(*g*) A droplet generator based on the resonant frequency of suspended drops has been developed. Other equipment is under construction.

324-08652-700-00

FLUID VELOCITY STANDARDS

(*d*) Experimental; basic.
(*e*) To compare current-meter calibrations obtained in a water tunnel with towing tank results, and to determine blockage and turbulence effects on various current meters in flowing water. Measuring techniques and instruments for low velocities will be evaluated.

(g) A high-performance closed-circuit 24-inch water tunnel with low velocity capability down to 0.1 fps is under construction. A temporary open-circuit gravity-flow 20-inch tunnel is being used for interim investigations. Comparison of Price meter calibrations for rod and cable suspensions was done in a towing tank and a report is in progress.

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U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, GEOPHYSICAL FLUID DYNAMICS LABORATORY, Post Office Box 308, Princeton University, Princeton, N.J. 08540. Dr. Joseph Smagorinsky, Director.

325-08449-450-00

GEOPHYSICAL FLUID DYNAMICS

(d) Basic research.
(e) Work is directed toward improving understanding of the physical and dynamical processes responsible for structure and variability of the atmosphere and oceans on a wide range of time and space scales. Numerical models are developed and simulation experiments are run on very large computers.
(h) **Bibliography of published papers is available. Reprints of papers are available upon direct request from the author.**
Benard Convection in a Rotating Fluid, R. C. J. Somerville, *J. Geophys. Fluid Dyn.* **II**, June 1971, 247-262.
Energy Spectrum of Small-Scale Internal Gravity Waves, I. Orlanski, *J. Geophys. Res.* **76**, 24, Aug. 1971, 3829-5835.
On the Breaking of Standing Internal Gravity Waves, I. Orlanski, submitted to J. Atmospheric Sciences.

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U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL OCEAN SURVEY, LAKE SURVEY CENTER, 630 Federal Building and U.S. Courthouse, Detroit, Mich. 48226.

326-08450-300-00

DETROIT RIVER TRANSIENT ANALYSIS BY THE IMPLICIT METHOD

(c) Dr. Frank H. Quinn, Chief, Lake Hydrology Branch.
(d) Applied research.
(e) A mathematical model of the Detroit River was developed using the implicit method to solve the unsteady flow equations of continuity and motion. Previous schemes using the implicit solution have been found to be stable under boundary conditions consisting of an upstream flow hydrograph and a downstream stage hydrograph. The applications have been in the solution of flood routing problems. A different situation arises in the analysis of flows in tidal estuaries and connecting channels, such as those on the Great Lakes. In these cases the boundary conditions consist of upstream and downstream stage hydrographs. This paper applies the implicit procedure to model a branched system representing the Detroit River, which connects Lakes St. Clair and Erie. The given boundary conditions are the Lake St. Clair and Lake Erie water surface elevations. The finite difference scheme chosen for this study uses a centering coefficient, θ, to determine the grid position at which the equations are evaluated. The stability of the procedure is then investigated for both the given boundary conditions and those consisting of an upstream flow hydrograph and downstream stage hydrograph.
(f) Completed.
(g) The use of the model is illustrated by computing the Detroit River flows during a severe Lake Erie wind tide which occurred in October, 1967. The simulated flow hydrographs show a flow variation greater than 100 percent occurring during a six-hour time period. Comparisons between the simulated and recorded hydrographs at the junction of the reaches show good agreement during the October transient with a maximum difference of about .3 foot. The stability of the model was found to be dependent upon the selection of the balancing coefficient θ. The model was found to be unconditionally stable for the values of θ given by $.5 < \theta \leq 1$, neutrally stable for $\theta = .5$, and unstable for $0 \leq \theta < .5$. The stable range was divided into a weakly stable zone of $.5<\theta<.6$ and a strongly stable zone of $.6 \leq \theta \leq 1$. No significant difference in model accuracy was found between the strongly stable values of θ. A value of $\theta \doteq .75$ was selected for use in all transient studies.
(h) Journal publication is pending.

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U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION, NATIONAL OCEAN SURVEY, NATIONAL OCEANOGRAPHIC INSTRUMENTATION CENTER, Rockville, Md. 20852. Gilbert Jaffe, Director.

327-08448-700-00

OCEANOGRAPHIC CURRENT METER EVALUATION

(c) Luther E. Bivins, Code C631.
(d) Investigations, evaluation.
(e) Test and evaluation of the latest in oceanographic water velocity measurement instrumentation. The program includes transducers utilizing the vortex shedding, electromagnetic and doppler measurement principles. The purpose of the program is to provide competent evaluation data on the performance of these instruments to the ocenaographic community.
(g) Preliminary tests were performed on an experimental vortex shedding current meter in 1971 and future tests are planned on a fully operational model. The evaluation of the electromagnetic principle applied to ocean current measurement instruments is underway with products from three different manufacturers undergoing tests. Basic problems were encountered with both flow and tow-type facilities creating excessive noise and calibration problems because of the extreme sensitivity of these instruments. Acoustic Doppler meters are planned for the near future.
(h) **Preliminary Tests on a Vortex Shedding Current Meter,** G. Appell, *NOIC Tech. Bull. DE-1002* (unpublished). Available from NOAA-NOS-NOIC, Code C634, Rockville, Md. 20852.

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U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL WEATHER SERVICE, Silver Spring, Md. 20910. Mr. Max A. Kohler, Associate Director of National Weather Service (Hydrology).

328-05664-810-00

STREAMFLOW FORECASTING RESEARCH

(c) Mr. Tor J. Nordenson, Hydrologist, Hydrologic R&D Laboratory.
(d) Theoretical and field; applied research.
(e) Research covering a wide range of hydrologic investigations is conducted with the primary objective to improve the operational river forecasting service. Activities include development and testing of conceptual models for continuous simulation of streamflow including optimizing techniques; improved methods for modeling the snowmelt runoff process; remote measurement of water equivalent of snow cover by aerial surveys of natural gamma radiation from the soil; development of numerical routing techniques; improved methods for measurement of precipitation including radar.
(g) Technique has been developed for optimizing the coefficients in the conceptual hydrologic models. Conceptual models are being applied to operational forecasting. Aerial

gamma radiation technique is undergoing field tests. Initial results indicate that the implicit numerical routing technique shows promise for the solution of very complex routing problems. A "digitizing radar experiment" is currently (1972) being conducted with four operational radar installations in south central United States to evaluate an automated radar-signal processing and data communications system for spatial, temporal and quantitative estimates of precipitation.

(*h*) **A Generalized Streamflow Simulation System,** R. J. C. Burnash, R. L. Ferral, presented at *Intl. Symp. on Mathematical Models in Hydrology*, July 1971, Warsaw, Poland.

Direct Search Optimization in Mathematical Modeling and a Watershed Model Application, J. C. Monro, *NOAA Tech. Memo. NWS HYDRO-12.*

Evaluation of Snow Water Equivalent by Airborne Measurement of Passive Terrestrial Gamma Radiation, E. L. Peck, V. S. Bissell, *Water Resour. Res.* 7, 5, Oct. 1971, pp. 1151-1159.

Aerial Measurement of Snow Water Equivalent by Terrestrial Gamma Radiation Survey, E. L. Peck, V. C. Bissell, presented at *15th General Assembly of IUGG*, Aug. 1971, Moscow, USSR.

Approaches to Measuring True Snowfall, L. W. Larson, *Proc. 29th Eastern Snow Conf.*, Feb. 1972, Oswego, New York.

An Experiment in Digitizing Weather Radar Data from a Four Station Network, S. G. Bigler, R. G. McGrew, M. St. Clair, *14th Radar Meteorology Conf., Amer. Meteorol. Soc.*, Nov. 1970, Tucson, Arizona.

328-06154-810-00

HYDROMETEOROLOGICAL RESEARCH FOR DESIGN CRITERIA

(*b*) Several Federal agencies engaged in water management programs.
(*c*) Mr. John F. Miller, Meteorologist, Chief, Water Management Information Division.
(*d*) Largely theoretical; basic and applied.
(*e*) Preparation of estimates of probable maximum precipitation, meteorological conditions for maximum snow accumulation and melting, hurricane wind fields, and rainfall intensity-frequency for design of spillways and other water-control structures and programs.
(*g*) Results are provided in the publications listed under (h).
(*h*) **Precipitation-Frequency Maps for Washington, Oregon, and Nevada,** Special Studies Branch, Office of Hydrology, National Weather Service, NOAA (individual maps), 1972.

Time Distribution of Precipitation in 4- to 10-Day Storms–Ohio River Basin, J. F. Miller, R. H. Frederick, to be published as *NOAA Tech. Memo, NWS HYDRO Series*, 1972.

Probable Maximum Precipitation, Mekong River Basin, *Hydrometeorological Rept. No. 46*, 152 pp., May 1970.

The Unprecedented Rains in Virginia Associated with the Remnants of Hurricane Camille, F. K. Schwarz, *Monthly Weather Review*, Nov. 1970.

Estimation of Maximum Floods, Chapter 2, Maximum Rainfall, V. A. Myers, *WMO Tech. Note No. 98*, 1969.

Probable Maximum Precipitation and Snowmelt Criteria for the Red River of the North and Souris River, J. T. Riedel, *Hydrometeorological Rept. No. 47* (in preparation).

Probable Maximum and Design Precipitation for Four Individual Basins in the Tennessee and Cumberland River Drainages, F. K. Schwarz, *Hydrometeorological Rept. No. 48* (in preparation).

Within Storm Precipitation Frequency Values, J. F. Miller, *Preprint No. 1316, ASCE Natl. Water Resources Engrg. Mtg.*, Phoenix, Ariz., Jan. 1971.

Physiographically Adjusted Precipitation-Frequency Maps, J. F. Miller, to be published in *Proc. Symp. Distribution of Precipitation in Mountainous Areas, Geilo, Norway, July–Aug. 1972.*

Precipitation-Frequency Atlas for Western United States, J. F. Miller, R. H. Frederick, R. J. Tracey, *NOAA Atlas* (in preparation).

328-08459-420-58

TIDAL SURGE FREQUENCY DISTRIBUTION–ATLANTIC AND GULF COASTS

(*b*) Department of Housing and Urban Development.
(*c*) Mr. John F. Miller, Meteorologist, Chief, Water Management Information Division.
(*d*) Largely applied research; some basic and theoretical development.
(*e*) Tidal frequency analyses for the open coast along the Atlantic and Gulf coasts of the United States. The objective is to define the frequency of all possible tidal stages, including the effects of the astronomically induced tide on the surges that can be generated by all possible types of severity of storms, including the more rare and severe hurricanes. These frequency estimates are used by the Federal Insurance Administration as the basis for setting rates in implementing federally sponsored insurance against the hazards or destruction by floods.
(*g*) Detailed results have been reported as below.
(*h*) **Joint Probability Method of Tide Frequency Analysis Applied to Atlantic City and Long Beach Island, N.J.,** V. A. Myers, *ESSA Tech. Memo. WBTM HYDRO 11*, Apr. 1970.

U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, PACIFIC OCEANOGRAPHIC LABORATORIES, University of Washington, Seattle, Wash. 98195, and the JOINT TSUNAMI RESEARCH EFFORT, University of Hawaii, Honolulu, Hawaii 96822. William D. Barbee, Captain NOAA, Acting Director.

330-08451-420-00

INTERNAL WAVE STUDIES

(*b*) Joint Pacific Oceanographic Lab.–University of Washington project.
(*c*) W. D. Barbee, Capt., POL, University of Washington WB-10, Seattle, Wash. 98195.
(*d*) Field experiment; basic research.
(*e*) The retardation of the earth's rotation rate indicates that the entire energy of the tides is dissipated in less than one day. Much of the energy is degraded through turbulence in shallow seas, but it appears that another large fraction is turned into internal tides in the deep sea. POL jointly with University of Washington is engaged in a program to determine the energy transform from surface to internal tides, and its ultimate dissipation.

330-08452-420-00

TSUNAMI RESEARCH

(*c*) Dr. Gaylord Miller, Joint Tsunami Research Effort, Univ. of Hawaii, Honolulu, Hawaii 96822.
(*d*) Theoretical with field measurement support; basic research with application phase (tsunami warning).
(*e*) Research directed toward acquiring practical solution to the problems of describing the effect of the following on the propagation of seismic sea waves; bottom irregularities; islands and coastlines; resonance functions of harbors and other inlets. In addition sensing systems are being developed to measure and telemeter data on tsunami waves in the open ocean for use in refining theory on deep ocean propagation, relationships between seismic disturbances and resultant tsunami characteristics, and methods for timely warnings.
(*g*) Techniques have been developed for monitoring long period (planetary) deep ocean waves by means of their magneto-telluric signatures and wave observations wire secured off Oahu. A permanent transponding tsunami gage was deployed in the North Pacific. Numerical techniques for describing harbor response to tsunamis were advanced.

330-08453-420-54

WAVE INTERACTION ON BEACHES

(*b*) National Science Foundation (NSF-International Decade of Ocean Exploration).
(*c*) Dr. Gaylord Miller, Joint Tsunami Research Effort, Univ. of Hawaii, Honolulu, Hawaii 96822.
(*d*) Field investigation; applied research.
(*e*) Basic objective is an exploration of water level fluctuations at the shoreline (and generally at frequencies lower than wind waves) as functions of offshore directional wave spectra and to gain ability to predict inshore sea surface elevation and water particle velocity in terms of offshore spectra.
(*g*) Theoretical and numerical studies have been started, and equipment is being assembled for field studies.

330-08454-420-54

OCEAN TSUNAMI MEASUREMENTS

(*b*) National Science Foundation (NSF-IDOE).
(*c*) Dr. Gaylord Miller, Joint Tsunami Research Effort, Univ. of Hawaii, Honolulu, Hawaii 96822.
(*d*) Field investigation; applied research.
(*e*) Measurement and telemetry of tsunami-frequency wave spectra. Measurements will be secured by deploying two open-ocean tsunami sensors of high resolution and obtaining data describing the background spectrum as functions of frequency direction and time. By means of numerical and analytic studies an attempt will be made to understand and predict the wave effects measured at shorelines by existing gages.
(*g*) Deep sea measuring systems have been tested *in situ*, and potential observational sites reviewed.

330-08455-450-54

NEAR SURFACE CIRCULATION IN A COASTAL UPWELLING ENVIRONMENT

(*b*) National Science Foundation (cooperatively with Oregon State University).
(*c*) Dr. David Halpern, POL, Univ. of Washington WB-10, Seattle, Wash. 98195.
(*d*) Experimental; basic research.
(*e*) Project designed to measure in a coastal upwelling environment (off the Oregon coast), the low frequency, offshore, near surface transport and the dynamic stability of the water between the surface and 35 meters. The relationship of the local winds to these two parameters will be evaluated. The time scale of an upwelling event will be inferred from variations in the offshore transport and compared with numerical models.
(*g*) Instrumentation requirements and the field experiment design have been substantially completed, preparatory to the initiation of the field work in the summer of 1972.

330-08456-450-54

NEAR SURFACE CIRCULATION

(*b*) National Science Foundation (NSF-IDOE).
(*c*) Dr. David Halpern, POL, Univ. of Washington WB-10, Seattle, Wash. 98195.
(*d*) Experimental; basic research.
(*e*) Investigate the near surface ocean response to time dependent wind stress. At a location not influenced by boundary currents, etc., wind, atmospheric pressure near surface currents and temperature structure will be measured from a moored buoy. Analyses will be directed to determining the response of the ocean in periods greater than the inertial period.
(*g*) Field measurements spanning about 45 days were successfully completed in the summer of 1971. Data are at present being analyzed.

330-08457-400-00

ESTUARINE AND COASTAL PROCESSES

(*c*) Dr. Glenn A. Cannon, POL, Univ. of Washington WB-10, Seattle, Wash. 98195.
(*d*) Field investigation; basic research.
(*e*) The hydrodynamics of estuarine and adjacent coastal zones must be understood if a rational approach to the management of these vital resources is to be secured. The flushing and circulation of these regions exert obvious and dominant influence on the dispersal of pollutants, maintenance of healthy fisheries, ship traffic control, seasonal flooding potential, crosional processes, etc., all of which have substantial economic importance. Almost nothing is known however of the dynamics of flushing and circulation in any other than the simplest of model estuaries. The project is designed to develop the relationships of the causal factors–winds, tides, ocean runoff, turbulent mixing processes, radiation, etc., with the resultant mass transport in Puget Sound and the adjacent coastal region, so as to provide a prediction capability for this area and to a limited extent, a body of generalized principles for application to other cstuaries and coastal zones.
(*g*) A preliminary field experiment was completed in the Washington State coastal zone, directed toward assaying the role of the Juan de Fuca submarine canyon on the coastal current regime for the fall season in 1971, and similar initial study of winter conditions within the main Puget Sound Basin was completed in 1972.

330-08458-450-00

OCEANOGRAPHIC PROCESS IN DEEP BASINS

(*c*) T. V. Ryan, POL, 1801 Fairview E., Seattle, Wash. 98102.
(*d*) Field investigation; basic research.
(*e*) The Panama Basin is an isolated basin in an area of high geothermal flux, probably associated with active tectonic forces. As such it provides an excellent site for the study of basin ventilation and circulation, and the thermal structure of deep water.
(*g*) A field investigation was completed in 1970 in which temperature, salinity, oxygen and bathymetric measurements were made. Published results present a circulation system through two main branches, driven largely by the geothermal flux. Residence time is cstimated at 175 years. Analyses of the thermal microstructure of the bottom water, measured with thermistor sensors continues.

U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, DIVISION OF GENERAL RESEARCH, Attention: 1530, Denver Federal Center, Denver, Colo. 80225. Chief, Division of General Research.

331-04794-360-00

VERTICAL STILLING WELL

(*d*) Experimental, theoretical; applied research.
(*e*) A plexiglass model was constructed to obtain optimum size and internal configuration of vertical stilling wells for a wide range of discharges. Promising designs were further tested in a larger vertical stilling well model.
(*f*) Completed.
(*g*) General design criteria for the VSW with a standard sleeve valve using dimensionless parameters related to sizing the stilling well based on design discharge, Q, and valve diameter, D, were established.
(*h*) Report in preparation.

331-04959-700-00

FLAT-BOTTOMED TRAPEZOIDAL VENTURI FLUMES

(*d*) Experimental; for design.
(*e*) A pilot study of a single flume was conducted to determine the best approach to a comprehensive program to generalize the design and calibration of this type water measuring device.
(*f*) Completed.
(*g*) The study has demonstrated the pilot flume that was tested to be an adequate measuring device.

(*h*) **Laboratory Studies of a Flat-Bottomed Trapezoidal Venturi Flume,** R. A. Dodge, *Rept. No. REC-ERC-72-14*, Apr. 1972.

331-04960-350-00

PROTOTYPE PIEZOMETRIC AND AIR DEMAND MEASUREMENTS OF 4- BY 4-FOOT TANDEM GATE–NAVAJO DAM, NEW MEXICO

(*d*) Field investigation; development.
(*e*) Piezometric measurements were obtained for the complete range of gate openings with a head of 164.5 feet for model-prototype comparison. Prototype air demand measurements were made simultaneously with piezometric values to evaluate adequacy of the air supply system. Further tests are planned at heads of about 230 feet and 300 feet to more fully evaluate the hydraulic characteristics of this gate and to check the model scaling.
(*f*) Inactive pending protoype measurements at higher heads.

331-05343-060-00

STRATIFIED FLOW

(*d*) Experimental and theoretical; applied research.
(*e*) A laboratory flume is being used to study the mechanism of selective withdrawal from stratified reservoirs. Temperature difference, monitored with thermistors, is being used to induce stratification.
(*g*) A tentative theory for use in designing selective outlets and a computer program for its solution were developed and examined with experimental data.
(*h*) **Hydraulics of Stratified Flow, Second Progress Report, Selective Withdrawal From Reservoirs,** D. L. King, *Rept. No. HYD-595*, Sept. 1969. A final report is in preparation.

331-06310-850-34

TEHAMA-COLUSA CANAL FISH CONCENTRATOR

(*b*) Fish and Wildlife Service.
(*d*) Experimental; design.
(*e*) A 1:2.5-scale model was used to develop the design of the fish concentrator through which the fingerlings are to be concentrated from a discharge of 140 cfs into a discharge of 5 cfs flowing to an electronic counting device.
(*f*) Completed.
(*g*) A fish concentrator was developed consisting of a sloping perforated plate screen 10 feet wide by 16 feet 3 inches long with adjustable orifices beneath the screen to control the flow through it to 135 cfs.
(*h*) **Hydraulic Model Studies of the Tehama-Colusa Canal Fish Concentrator, Central Valley Project, Calif.,** G. L. Beichley, *Rept. No. REC-ERC-71-4*, Jan. 1971.

331-06317-840-00

DRAINAGE FROM SLOPING IRRIGATED LAND

(*d*) Experimental; applied research.
(*e*) A 60-foot long by 2-foot wide by 2-1/2-foot deep sand tank that can be tilted from 0 to 12 percent was constructed. One side of the tank has transparent plastic panels. Horizontal drains at right angles to the sand tank sides were placed at 6-foot intervals along the sand tank. The drains which simulate agricultural drains were 2 feet above the tank bottom. A sprinkler system distributes water evenly over the sand surface to simulate the application of irrigation water. Tests were made for 6-foot and 12-foot drain spacings at four different recharge rates and for sand tank slopes of 0, 2-1/2, 5, 7-1/2, and 10 percent slopes. Measurements of the groundwater table location and drain discharges were made. Dye tests to show flow lines were made at four different recharge rates and at a 2-1/2 percent slope. Pressure measurements at approximately 200 points between tile drains and the impermeable barrier were made from pressure taps installed in the plexiglass side for 12 test conditions.
(*f*) Completed.
(*g*) See 1970 issue.
(*h*) **Drainage from Level and Sloping Land,** E. J. Carlson, *Rept. No. REC-ERC-71-44*, Dec. 1971.
Laboratory Tests to Study Drainage from Sloping Land, E. R. Zeigler, *Rept. No. REC-ERC-72-4*, Jan. 1972.

331-06318-210-32

PIPING OF BRINE BETWEEN EVAPORATORS IN A 2.5-MGD UNIVERSAL DESALINATION PLANT

(*b*) Office of Saline Water.
(*c*) Mr. P. G. Tomalin, Office of Saline Water, Distillation Division, U.S. Dept. of the Interior, Washington, D.C. 20240.
(*d*) Experimental; design.
(*e*) A 1:2.33-scale model study was conducted to determine the driving force required to discharge a given quantity of 118°F, 5 percent salt saturated brine through the most critical of the interstage module piping and to develop design modifications as dictated by the results of the tests.
(*f*) Completed.
(*g*) Pipeline losses including entrance and exit losses exceed the available driving force between the last two modules and a loss coefficient curve for the system was determined for a range of Reynolds numbers.
(*h*) **Hydraulic Model Studies of Interstage Module Piping in the 2.5-MGD Universal Desalination Plant–Office of Saline Water,** G. L. Beichley, *Rept. No. REC-OCE-70-16*, May 1970.

331-06321-340-00

DRAFT TUBE SURGES

(*d*) Theoretical and experimental; basic and applied research.
(*e*) Surging flow occurring in the draft tubes of Francis turbines causes rough operation and often produces power swings. The surging flow is produced by the phenomenon known as vortex breakdown, creating a stable unsteady flow condition. The purpose of the project is to investigate the basic nature of draft tube surging, to correlate model test and field test data, and to investigate the addition of appurtenances in the draft tube and changes in the draft tube geometry itself as a means of eliminating or reducing the magnitude and range or occurrence of the surging. An air model has been used in the laboratory study.
(*g*) In the laboratory air model, surge data were obtained for over 50 distinct draft tube shapes. Some of the draft tubes were actual models of prototypes, but most were simple geometrical shapes or combinations thereof consisting of straight circular cylinders, truncated diverging cones, and circular cross-section elbows. The studies show that the degree of divergence of the draft tube throat is the most significant geometric feature affecting surging characteristics. Bends and relative length have lesser influence. Increasing the draft tube throat expansion angle generally reduces the range of surging as well as reducing the amplitude when surging does occur. Good comparison was obtained between results of the laboratory studies and manufacturer's model tests for the Grand Coulee pump-turbine draft tube.
(*h*) **Observations of Unsteady Flow Arising After Vortex Breakdown,** J. J. Cassidy, H. T. Falvey, *J. Fluid Mech.* **41,** Pt. 4, pp. 727-736, 1970.
Frequency and Amplitude of Pressure Surges Generated by Swirling Flow, H. T. Falvey, J. J. Cassidy, *Trans. IAHR Symp., Stockholm 1970*, Pt. 1, Paper E1.
Draft Tube Surges–A Review of Present Knowledge and an Annotated Bibliography, H. T. Falvey, *Rept. No. REC-ERC-71-42*, Dec. 1971.
Influence of Draft Tube Shape on Surging Characteristics, U. J. Palde, *Mtg. Preprint 1589, ASCE Natl. Water Resources Engrg. Mtg.*, Atlanta, Ga., Jan. 1972.

331-06322-340-00

GRAND COULEE DAM AND THIRD POWERPLANT

(*d*) Experimental; design.

(*e*) A 1:120-scale model of the Third Powerplant and all existing features at Grand Coulee Dam aided in the development of the forebay channel and tailrace of the plant which will have an ultimate capacity of 7,200 MW from 12 units.
(*f*) Completed.
(*g*) The shapes of the forebay and tailrace channels for both a 6- and a 12-unit plant have been established. Velocities and water surface profiles have been determined. Tendencies for vortex formation at the penstock entrances were investigated.
(*h*) Report in preparation.

331-06323-340-00

GRAND COULEE THIRD POWERPLANT PENSTOCKS

(*d*) Experimental; for design.
(*e*) A 1:41.75-scale model aided in the development of the entrances and elbows for the 40-foot diameter penstocks.
(*f*) Completed.
(*g*) A penstock entrance that is much smaller and shorter than entrances designed by current criteria was found to have satisfactory flow and pressure conditions and a very small head loss coefficient. The tests also indicate that an accelerating elbow just upstream of the generator entrance will be equally efficient with a curvature radius equal to either 2-1/2 or 3-1/2 times the penstock diameter.
(*h*) Report in preparation.

331-06325-350-00

CONCONULLY DAM SPILLWAY

(*d*) Experimental; for design.
(*e*) A 1:18-scale sectional model aided in the development of a baffled chute for use as an energy dissipator for a 70-foot high spillway having a unit discharge of 78 cfs per foot of width.
(*f*) Completed.
(*g*) Tests showed the baffled chute to be very effective in limiting the acceleration of the flow down the spillway and in minimizing erosion tendencies at the end of the chute.
(*h*) **Studies to Determine the Feasibility of a Baffled Apron Drop as a Spillway Energy Dissipator, Conconully Dam Spillway, Okanogan Project, Washington,** T. J. Rhone, *Rept. No. REC-ERC-71-29*, June 1971.

331-06328-350-00

TIBER DAM AUXILIARY OUTLET WORKS

(*d*) Experimental; design.
(*e*) A 1:17.53-scale model is being used to develop the design of a drop inlet from the existing canal outlet tunnel to the new auxiliary outlet.
(*f*) Completed.
(*g*) A curved deflector in the crown of the canal tunnel directly over the drop inlet has been developed to intercept the swirling motion of flow entering the drop inlet; and, thus, improve the flow pattern throughout the outlet tunnel downstream from the slide gate control.
(*h*) **Hydraulic Model Studies of Tiber Dam Auxiliary Outlet Works, Missouri River Basin Project, Montana,** G. L. Beichley, *Rept. No. REC-OCE-70-44*, Oct. 1970.

331-06329-350-00

YELLOWTAIL DAM SPILLWAY REPAIRS

(*d*) Experimental; for design.
(*e*) A model of the tunnel spillway aided in the development of an aeration device to introduce air into the flowing water to prevent the reoccurrence of severe cavitation erosion damage in the vertical bend of the tunnel and immediately downstream.
(*f*) Completed.
(*g*) An aeration slot in the tunnel was successfully developed and has since been tested and proven to perform as intended in the prototype.
(*h*) **Hydraulic Model Studies of Aeration Devices for Yellowtail Dam Spillway Tunnel,** D. Colgate, *Rept. No. REC-ERC-71-47*, Dec. 1971.

331-06330-350-00

FOLSOM DAM SPILLWAY REPAIRS

(*d*) Experimental; for design.
(*e*) A sectional model of the junction of Folsom Spillway and one outlet conduit was constructed and tested to determine a means of preventing cavitation damage to the spillway face when spillway releases are made.
(*f*) Completed.
(*g*) An eyebrow was developed to deflect spillway flow away from the outlet conduit spillway junction eliminating cavitation conditions for spillway operation. A splitter pier to aerate the junction for simultaneous spillway outlet releases was abandoned because it would be extremely difficult to anchor to the spillway face.
(*h*) **Hydraulic Model Studies of Folsom Spillway-Outlet Junction,** T. J. Isbester, *Rept. No. REC-ERC-71-12*, Feb. 1971.

331-07014-360-00

JACKSON LAKE DAM BAFFLE BLOCKS

(*d*) Experimental; design.
(*e*) A 1:15-scale model was used to determine corrective measures needed to prevent additional erosion in the downstream channel. Two energy dissipator configurations were tested on the downstream apron. Several sluice operating arrangements were also tested.
(*f*) Completed.
(*g*) An end sill on the downstream apron yielded a slight improvement over the existing baffle block configuration in reducing downstream erosion. However, the improvement did not warrant a change in the existing configuration. Sluice operating arrangements proved to be a more effective means of reducing downstream erosion.
(*h*) **Hydraulic Model Studies of Jackson Lake Dam Baffle Blocks,** P. H. Burgi, *Rept. No. REC-OCE-70-12*, Mar. 1970.

331-07015-360-68

UTE DAM OUTLET WORKS

(*b*) New Mexico Interstate Stream Commission.
(*d*) Experimental; for design.
(*e*) A 1:8-scale model aided in the development of an enclosed basin type energy dissipator for a 48-inch horizontal cylinder (fixed cone) control valve discharging into a concrete-lined channel.
(*f*) Completed.
(*g*) An enclosed basin with flared walls and ceiling to intercept the cone-shaped jet followed by a 45° deflector on walls and ceiling with baffle blocks on floor was developed to contain the jet and dissipate the energy before allowing the flow to enter the channel.
(*h*) **Hydraulic Model Studies of an Energy Dissipator for a Fixed-Cone Valve at the Ute Dam Outlet Works,** G. L. Beichley, *Rept. No. REC-OCE-70-11*, Mar. 1970.

331-07016-350-60

TOA VACA DAM SPILLWAY

(*b*) Puerto Rico Water Resources Authority.
(*c*) Rafael V. Urrutia, Executive Director, Puerto Rico Water Resources Authority, San Juan, Puerto Rico.
(*d*) Experimental; for design.
(*e*) A 1:48-scale model aided in the development of the hydraulic design of the radial gate-controlled open channel chute spillway with combination stilling basin and flip bucket.
(*f*) Completed.
(*g*) The combination stilling basin and flip bucket was modified along with the discharge channel to meet the design discharge requirements.

(*h*) **Hydraulic Model Studies of Toa Vaca Dam Spillway–Puerto Rico Water Resources Authority,** G. L. Beichley, *Rept. No. REC-OCE-70-42*, Oct. 1970.

331-07017-320-00

WAHLUKE BRANCH CANAL LATERALS–BLOCK 25

(*d*) Experimental; for design.
(*e*) A 1:6-scale model of one of the canal lateral turnouts aided in the design of the turnouts.
(*f*) Completed.
(*g*) A drop inlet through a grizzly in the floor of the canal was developed for use along with a constant-head orifice turnout to discharge the design flow from the canal in a satisfactory manner regardless of total main canal flow.
(*h*) **Hydraulic Model Studies of a Turnout from Lateral WB38 Chute–Wahluke Branch Canal–Washington,** G. L. Beichley, *Rept. No. REC-OCE-70-33*, Aug. 1970.

331-07018-320-00

MAIN CANAL BACON SIPHON AND TUNNEL

(*d*) Experimental; for design.
(*e*) A 1:49.8-scale model was used to aid in developing the design of the entrance and exit canal transitions to the two siphons and to determine the size of the main canal and the design of the canal bifurcations both upstream and downstream of the siphons.
(*f*) Completed.
(*g*) Wave suppressors were developed for use with the two exit transitions to provide a smoother water surface and more uniform flow distribution in the canal downstream. Since one of the siphons was an existing structure, the two wave suppressors developed were not alike.
(*h*) **Hydraulic Model Studies of Bacon Siphons, Columbia River Project, Washington,** G. L. Beichley, 1972, in preparation.

331-07019-350-00

FLOW AERATION DOWNSTREAM OF SLIDE GATES TO PROTECT AGAINST CAVITATION EROSION

(*d*) Experimental; for design.
(*e*) A slide gate model is used to aid in the development of methods to induce air into the flow from existing slide gate installations and for general use in proposed new installations.
(*f*) Completed.
(*g*) Air supply slots in the walls together with a floor deflector to lift the jet from the floor at the gate frame was developed for the existing outlet works at Palisades Dam and the existing auxiliary outlet works at Navajo Dam. An offset away from the flow in the conduit floor and walls of proposed outlets at Pueblo Dam, Crystal Dam (earth design), and Teton Dam were developed. General design criteria were established for use in slide gate outlet designs at future installations.
(*h*) **Hydraulic Model Studies of Chute Offsets, Air Slots, and Deflectors for High-Velocity Jets,** G. L. Beichley, 1972, in preparation.

331-07020-340-88

HORSE MESA DAM HYDRO-ELECTRIC EXPANSION

(*b*) Salt River Project.
(*c*) Salt River Project, P.O.Box 1980, Phoenix, Ariz. 85001.
(*d*) Experimental; design.
(*e*) A 1:24-scale model was used to verify the hydraulic design of the inlet-outlet structure for a new pump-turbine facility.
(*f*) Completed.
(*g*) A satisfactory structure with gradually expanding outflow from the penstock during the pump cycle and smooth flow into the penstock for the generation cycle was developed.
(*h*) **Hydraulic Model Studies of the Reservoir Inlet-Outlet Structure for Horse Mesa Pump-Storage Unit, Salt River Project, Arizona,** P. L. Johnson, *Rept. No. REC-ERC-71-34*, Sept. 1971.

331-07021-340-88

MORMON FLAT DAM HYDRO-ELECTRIC EXPANSION

(*b*) Salt River Project.
(*c*) Salt River Project, P.O. Box 1980, Phoenix, Ariz. 85001.
(*d*) Experimental; design.
(*e*) A 1:19-scale model was used to verify the hydraulic design of the intake-outlet structure for a new pump-turbine facility. Gradual expansion of the outflow from the penstock during the pumping cycle and smooth flow into the penstock for generating flow were sought. Included in the model are the intake-outlet structure and the 18-foot diameter penstock down to the scrollcase.
(*f*) Completed.
(*g*) See 1970 issue for details.
(*h*) **Hydraulic Model Studies of the Intake Outlet Structure for the Pump Generation Facility at Mormon Flat Dam–Salt River Project, Arizona,** T. J. Rhone, *Rept. No. REC-ERC-71-31*, Aug. 1971.

331-07022-340-00

GRAND COULEE PUMP-TURBINE INTAKE AND TRANSITION

(*d*) Experimental; for modification.
(*e*) Laboratory studies are continuing to determine the benefits which could be derived by lowering the floor of the Banks Lake Feeder Canal.
(*g*) Studies concerning the canal headwall and siphon elbow inlet transitions have been completed.

331-07025-700-00

SUPPRESSED RECTANGULAR WEIR STUDY

(*d*) Experimental; applied research.
(*e*) Laboratory studies were performed on a 4-foot wide weir box turnout structure for irrigation use with closed pipe inflow. The purpose of the study was to determine the shortest box and the best stilling baffle arrangement to produce a reasonably smooth water surface and uniform velocity profile upstream of a suppressed rectangular weir for discharges up to 10 cfs.
(*f*) Completed.
(*g*) The minimum length of the stilling box and a satisfactory baffle arrangement were determined which provided approach conditions that were suitable for establishing a rating curve for the weir up to about 12 cfs. The rating curve differs from accepted standard suppressed weir formulas because of the nonstandard approach conditions and method of measuring head. The Kindsvater-Carter method has been used to fit an equation to the rating curve data.
(*h*) Report in preparation.

331-07026-350-56

PA MONG DAM SPILLWAY BUCKET ENERGY DISSIPATOR

(*b*) The committee for Coordination of Investigations of the Lower Mekong Basin and the Agency for International Development.
(*d*) Experimental; design.
(*e*) A 1:55-scale model was constructed to determine the optimum spillway bucket radius and tooth and spacing widths for the tailwater conditions at the Pa Mong damsite.
(*f*) Completed.
(*g*) A 13.5-meter radius slotted bucket resulted in the smoothest water surface conditions. A 21-meter long apron placed at bucket lip elevation produced very favorable ground roller action.
(*h*) **Hydraulic Model Studies of the Spillway Bucket Energy Dissipator, Pa Mong Dam, Pa Mong Project, Laos and Thailand,** P. H. Burgi, *Rept. No. REC-OCE-70-17*, May 1970.

331-07027-350-00

PUEBLO DAM SPILLWAY

(*d*) Experimental; for design.

(*e*) A 1:56-scale model was used to study the free-fall spillway and plunge pool-type stilling basin for Pueblo Dam.
(*f*) Completed.
(*g*) The basin was designed to still a flood of 30,000 cfs (400-year flood) while the spillway was designed to pass 191,500 cfs. To minimize the magnitude of dynamic pressure on the floor of the plunge pool and improve the stilling action, the pool floor was lowered 9 feet.
(*h*) **Hydraulic Model Studies of the Pueblo Dam Spillway and Plunge Basin,** T. J. Isbester, *Rept. No. REC-ERC-71-18*, June 1971.

331-07028-350-00

AUBURN SPILLWAY GATE STUDY

(*d*) Experimental; for design.
(*e*) a 1:24-scale model was built to study the 11- by 17-foot downstream seal fixed-wheel gates for the spillway at Auburn Dam. The model conduit was offset away from the flow downstream of the gate frame to provide aeration to the flow boundary.
(*g*) To date the invert of the conduit does not aerate except at fully opened gate. A larger sectional model will be built to study the gate slot area and offsets. An upstream seal concept was first tested and then abandoned when it was found that heavy flow into the large gate slots could not be eliminated.

331-07030-320-00

CANAL AUTOMATION

(*d*) Experimental development; applied research.
(*e*) The purpose of the laboratory study is to continue the development of downstream controls for automation of canal gates and upstream controls for a canal turnout used for delivery and measurement of water.
(*g*) A downstream controller was successfully operated in the laboratory and installed at a canal section for satisfactory operation of the canal gate. Preliminary experiments on the turnout control indicate the possibility of designing a satisfactory device.
(*h*) **Study of Hydraulic Filter Level Offset (Hy Flo) Equipment for Automatic Downstream Control of Canals,** J. C. Schuster, E. A. Serfozo, *Rept. No. REC-ERC-72-3*, Jan. 1972.

331-07031-710-52

DISCHARGE MEASUREMENTS USING RADIOISOTOPES IN HIGH-HEAD TURBINES AND PUMPS

(*b*) U.S. Atomic Energy Commission.
(*d*) Experimental laboratory and field investigation; basic and applied research.
(*e*) The purpose of the study was to establish the feasibility of and develop procedures and equipment for making radioisotope discharge measurements accurately, quickly, and with a minimum of personnel and equipment.
(*f*) Completed.
(*g*) Radioisotope techniques and equipment were developed at program completion to measure flow rates with a 2 sigma error estimated to be ±1.5 percent. In the five phase program studies were made of injection equipment, pipe lengths necessary for satisfactory mixing, sampling equipment, radiation counting techniques, and probable errors in the method. The study included using radiotracers in the velocity method and in various forms of the dilution method including integrated sample, constant rate injection, and total count. A final paper summarizes the conclusions of various phases of the program and the results of satisfactorily applying three dilution techniques in measuring flow rates in 6- and 8-foot diameter penstocks for two high-head powerplants.
(*h*) **Discharge Measurements Using Radioisotopes in High Head Turbines and Pumps,** *USAEC Rept. No. TID23737*, Sept. 1966.
Discharge Measurements Using Radiosotopes in High Head Turbines and Pumps at Flatiron Power and Pumping Plant, *USAEC Rept. No. TID25177*, Dec. 1968.
Discharge Measurements Using the Radiosotope Velocity, Integrated Sample, Dilution, and Total-Count Methods at Flatiron Power and Pumping Plant, *USAEC Rept. No. TID25185*, July 1969.
Discharge Measurements Using Radioisotopes at Flatiron Power and Pumping Plants, *USAEC Rept. No. TID25395*, Aug. 1970.
Radioisotopes and Turbine Flow Measurements, Preprint 1294, *ASCE Natl. Water Resour. Engrg. Mtg.*, Phoenix, Ariz., Jan. 1971.

331-07032-860-00

REAERATION OF STREAMS AND RESERVOIRS

(*d*) Experimental and theoretical; applied research.
(*e*) Emphasis is being placed on development of equipment and methods for reaeration of large volumes of water. Comparison of efficiencies will be emphasized.
(*g*) A state-of-the-art review and a survey of western regional needs for reaeration were completed. An interdisciplinary team was formed to plan and manage the reaeration research program.
(*h*) **Reaeration of Streams and Reservoirs–Analysis and Bibliography,** D. L. King, *Rept. No. REC-OCE-70-55*, Dec. 1970.

331-07034-850-00

PUEBLO FISH HATCHERY OUTLET WORKS

(*d*) Experimental; design.
(*e*) A 1:60-scale model was used to determine the optimum locations of selective outlets for the water supply to a proposed fish hatchery. A mathematical model was used to determine the stratification patterns to be simulated in the hydraulic model.
(*f*) Completed.
(*g*) The purpose of the study was accomplished including determining the effects and advisability of removing the barrier dam.
(*h*) **Selective Withdrawal Studies for the Fish Hatchery Outlets at Pueblo Dam–Mathematical and Physical Models,** D. L. King, *Rept. No. REC-ERC-71-32*, Aug. 1971.

331-07035-350-00

AUBURN DAM SPILLWAYS

(*d*) Experimental; design.
(*e*) A 1:72 model is used to study flow conditions in the chutes, stilling basins, and river channel. The service spillway is located on the left abutment and discharges into a hydraulic jump stilling basin. The emergency spillway on the right abutment terminates in a flip bucket. Each spillway discharges up to 160,000 cfs through controlled orifices located up to 150 feet below the maximum water surface. The model is also being used to determine optimum sequencing of the orifices.
(*g*) Tests confirmed that the hydraulic jump energy dissipator for the service spillway was satisfactory. Testing was continued to develop alternate means for distributing the flow from the service spillway. Efforts have been directed toward terminating the chute about midway between the orifice spillway and the river channel. A flip-type bucket is being developed to deflect the flow into an excavated plunge pool in the river channel.

331-08460-700-00

LABORATORY INVESTIGATIONS OF COMBINED VERTICAL FLOWMETER AND FLOW-CONTROLLERS

(*d*) Experimental; operation.
(*e*) Head loss, accuracy and operational tests on used and new devices to check applicability for use in closed conduit irrigation systems and to determine their reaction to pump operations.
(*f*) Completed.
(*g*) Difficulties such as leakage, failure to recognize closure initiations, and slowness of or even refusing to control flow were experienced. Laboratory tests also indicated that pump operations can cause temporary overdelivery.

(*h*) **Investigation of a 10-inch Vertical Flowmeter, Flow Controller and Integrator,** C. P. Buyalski, R. A. Dodge, *Rept. No. REC-OCE-70-54*, Dec. 1970.
Laboratory Investigation of Combined Vertical Flowmeter and Flow-Controllers Used for Irrigation Water Delivery, D. B. Garduno, R. A. Dodge, *Rept. No. REC-ERC-71-48*, Dec. 1971.

331-08461-350-00

SCOGGINS DAM AERATOR OUTLET TO THE FISH TRAP

(*d*) Experimental; applied research.
(*e*) A 1:3.33-scale model aided in the development of an enclosed-basin type energy dissipator for a 20-inch horizontal cylinder (fixed-cone) control valve used to aerate the flow into a constant head orifice structure before distributing the flow to various areas of the fish trap.
(*f*) Completed.
(*g*) An enclosed basin with flared walls, floor, and ceiling to intercept the cone-shaped jet followed by a 45° deflector on walls and ceiling with baffle blocks on floor was developed to contain the jet and dissipate the energy before allowing the flow to enter the constant head orifice structure. The purpose of using this type of valve and energy-dissipator was to expose the flow to a considerable amount of air for the absorption of oxygen into the flow before delivering it to the fish trap.
(*h*) **Hydraulic Model Studies of Scoggins Dam Aerator Outlet to the Fish Trap, Tualatin Project, Oregon,** G. L. Beichley, 1972. (Report to be prepared.)

331-08462-320-00

TETON CANAL OUTLET WORKS

(*d*) Experimental; for design.
(*e*) A 1:5.66-scale model aided in the development of a 3-diameter expansion energy dissipator for flow from a 20-inch jet flow gate.
(*f*) Completed.
(*g*) Results provided a discharge rating of the gate, losses through the system, and incipient cavitation coefficients. It was determined that high back pressure on the system reduced the potential for cavitation.
(*h*) Report in preparation.

331-08463-300-00

ICE CONTROL STRUCTURE ON THE NORTH PLATTE RIVER

(*d*) Experimental; design.
(*e*) A 1:24 undistorted scale river model was constructed to optimize the design of an existing ice control structure. Ice was simulated in the model with 1/8-inch hemispherical particles of low density polyethylene plastic.
(*f*) Completed.
(*g*) Recommendations were that channel cross-sections be modified to improve the flow conditions at the control structure site; that two-channel constrictions be used downstream of the control structure to decrease the Froude number at the control structure site; and that several modifications to the control structure be made which would improve the ice retention capability.
(*h*) **Ice Control Structure on the North Platte River–A Hydraulic Model Study,** P. H. Burgi, *Rept. No. REC-ERC-71-46*, Dec. 1971.

331-08464-860-00

SURVEY OF REAERATION NEEDS ON BUREAU OF RECLAMATION PROJECTS

(*d*) Field investigation; research.
(*e*) The Reaeration Research Program Management Team was formed to investigate the Bureau of Reclamation's needs for research in reaeration of rivers, reservoirs, canals, and aquifers. To determine the extent of problems on Bureau projects due to dissolved oxygen deficiency, a questionnaire survey was made of operating personnel in the USBR regions and at the E&R Center.
(*f*) Complete.
(*g*) A report gives a summary and complete results obtained from the questionnaire. An improved quality of water in certain Bureau reservoirs and streams may be required to meet State standards. It may be necessary to incorporate reaeration facilities in future designs for new construction. A suggestion of research needs and research opportunities on Bureau projects is given.
(*h*) **Survey of Reaeration Needs on Bureau of Reclamation Projects,** E. J. Carlson, Mar. 1972.

331-08465-390-00

ICE FORMATION–A REVIEW OF THE LITERATURE AND BUREAU OF RECLAMATION EXPERIENCE

(*d*) Theoretical; development of ice research program.
(*e*) A review of the literature and Bureau of Reclamation experience related to ice formation was conducted to develop a research program.
(*g*) A report of the review has been published. A research team has been established to direct an on-going ice research program.
(*h*) **Ice Formation–A Review of the Literature and Bureau of Reclamation Experience,** P. H. Burgi, P. L. Johnson, *Rept. No. REC-ERC-71-8*, Sept. 1971.

331-08466-360-06

ENERGY DISSIPATORS FOR UNDERDRAINS

(*b*) Forest Service.
(*c*) United States Department of Agriculture, San Dimas, Calif. 91773.
(*d*) Experimental; development.
(*e*) Model studies were made to develop self-cleaning energy dissipators to be used at the outlet ends of corrugated-metal pipe culverts under trails and roadways.
(*f*) Completed.
(*g*) A basic energy dissipator design was developed which may be used with either annular or helical corrugated metal pipe underdrains. The pipe may be up to 36-inch diameter, and with slopes from level up to 66 percent. The dissipator may be shop fabricated with light weight metal, and assembled at the installation site.
(*h*) **Hydraulic Model Studies of Corrugated-Metal Pipe Underdrain Energy Dissipators,** D. Colgate, *Rept. No. REC-ERC-71-10*, Jan. 1971.

331-08467-350-00

MT. ELBERT PUMP-STORAGE POWERPLANT

(*d*) Experimental; design.
(*e*) A 1:23.23-scale model was used to verify the hydraulic design of the inlet-outlet structure for a new pump turbine facility.
(*g*) A satisfactory structure with gradually expanding outflow from the penstock during the pump cycle and smooth flow into the penstock for the generation cycle was developed. Study of possible generation cycle vortex formation produced a satisfactory vortex suppression structure.
(*h*) **Hydraulic Model Studies of the Forebay Reservoir Inlet-Outlet Structure for Mt. Elbert Pumped-Storage Powerplant, Fryingpan-Arkansas Project, Colorado,** P. L. Johnson, *Rept. No. REC-ERC-72-5*, Jan. 1972.

331-08468-860-00

PREDICTION OF TEMPERATURES IN RESERVOIRS

(*d*) Theoretical; applied research.
(*e*) Several available mathematical models are being evaluated for applications in predicting temperature patterns in existing and future reservoirs. Predictions are being compared with field data on existing reservoirs for verification of the models.

331-08469-360-00

PLUNGE BASINS FOR SLIDE GATE OUTLETS

(*d*) Experimental; applied research.

(e) Model studies are being conducted using a 1-inch by 1-inch slide gate to determine the depth, breath, and length of scour in gravel from which to prepare design criterion for riprap lined plunge basins.

331-08470-890-00

GRAVEL PACKS IN WELLS

(d) Experimental; applied research.
(e) Laboratory tests were made to simulate placing gravel-pack material in a well during construction. The purpose of the studies was to show the degree to which graded gravel material segregates and forms layers when placed in a wellhole containing water.
(f) Completed.
(g) When gravel pack material is added intermittently, layering occurs due to segregation of the gravel-pack material as it deposits. Segregation can be overcome by adding gravel-pack material continuously. Graphs were prepared to show the extra depth of gravel pack needed to assure uniform pack material throughout the full screen depth.
(h) Report in preparation.

331-08471-340-00

AUBURN DAM BUTTERFLY VALVE STUDIES

(d) Experimental; for design.
(e) Laboratory studies were initiated to compare the hydraulic losses caused by butterfly valves installed as guard valves upstream from turbines. The study will compare valves with geometrically similar leafs but with different body configurations and different locations with respect to the turbine.

331-08472-750-00

ATMOSPHERIC SIMULATION

(d) Experimental; research.
(e) A study to determine feasibility of using salt water density gradients in a model to represent atmosphere and to check effect of vertical distortion on scaling.

331-08473-390-00

AUTOMATIC CONSTANT HEAD ORIFICE TURNOUT

(d) Experimental; applied research.
(e) Tests to determine the operational characteristics of component parts of a system that delivers constant discharge under a variable upstream head with a constant differential maintained on the orifice measuring gate by means of a motorized downstream control gate.

331-08474-890-00

ICE EMBRYO NOZZLES FOR CLOUD SEEDING

(d) Experimental; applied research.
(e) Miniature supersonic nozzles are being developed and tested for generation of ice nuclei from compressed air; for use in seeding super-cooled clouds and fog.
(g) Results show high production of ice nuclei for cloud temperatures well below freezing; work is continuing to optimize a nozzle design for use with cloud temperatures only slightly below freezing.

331-08475-890-00

SPRAY NOZZLES FOR CLOUD SEEDING AND OTHER APPLICATIONS

(d) Experimental; applied research.
(e) Commercial devices and laboratory developed devices are being tested for use in spraying hygroscopic liquids for cloud seeding and for spray drying and other miscellaneous applications.
(g) Various devices including self-impinging jets, target-impinging jets, and acoustic nozzles have been tested. Work is continuing, to minimize the energy requirement for producing specific droplet sizes.

331-08476-350-00

CRYSTAL ARCH DAM OUTLET WORKS

(d) Experimental; design.
(e) A 1:13.6-scale model of the outlet works was used to study the flow conditions in the vertical inlet tower, the horizontal bellmouth entrance from the tower to the outlet conduit, and the jet flow gate which discharges submerged to the plunge pool.

331-08477-350-00

CRYSTAL ARCH DAM SPILLWAY

(d) Experimental; design.
(e) 1:36-scale model was used to aid in the development of a flip-type spillway and plunge pool design.

331-08478-350-00

HYDRAULIC MODEL VORTEX STUDY FOR GRAND COULEE THIRD POWERPLANT

(d) Experimental; applied research.
(e) A model was used to study the problem of air-entraining vortices occurring in the forebay channel at the penstock intakes.
(f) Completed.
(g) There appeared to be a danger that air-entraining vortices would occur over the intakes. Means of elimination or control of these vortices were limited to the development of a raft system.
(h) Report in preparation.

U.S. DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY, WATER RESOURCES DIVISION, Washington, D.C. 20242. Warren S. Daniels, Chief, Planning Section.

332-02950-220-00

SEDIMENT TRANSPORT AND CHANNEL ROUGHNESS IN NATURAL AND ARTIFICIAL CHANNELS

(c) Mr. Thomas Maddock, Jr., U.S. Geological Survey, Tucson, Ariz.
(d) Basic research.
(e) Field and laboratory studies, original and other investigations will be analyzed in terms of sediment movement, channel roughness, shear distribution in channel prism and other effects on shape of natural channels.
(g) Relations between velocity and sediment load have been developed. Relations involving slope are shown to be indeterminate within certain limits.
(h) **The Behavior of Straight Open Channels with Movable Beds,** T. Maddock, *USGS Prof. Paper 622-A*, 1969.
Economic Aspects of Sedimentation, T. Maddock, Chapter 6, *Manual on Sedimentation*, *ASCE*, *J. Hydraul. Div.*, 1969.
Indeterminate Hydraulics of Alluvial Channels, T. Maddock, *ASCE Proc.*, *J. Hydraul. Div.* **96,** HY11, 2309-2323, 1970.
Hydraulic Relations for Sand Bedded Streams, T. Maddock, *Sedimentation Symp. to honor Prof. H. A. Einstein*, Ed., H. W. Shen, Ft. Collins, Colo. 1971.

332-04787-070-00

TRANSPORT PROCESSES IN FLUID FLOWS

(c) Dr. Akio Ogata, U.S. Geological Survey, P.O. Box 657, Honolulu, Hawaii.
(d) Experimental and theoretical study; basic research.
(e) Theoretical and laboratory study of microscopic and macroscopic aspects of flow through porous media.
(h) **Hydraulic Sand-Model Studies of Two Fluid Flow,** J. M. Cahill, report in review.

332-05604-200-00

MECHANICS OF FLUID RESISTANCE

(*c*) Dr. H. J. Tracy, U.S. Geological Survey, WRD, 900 Peach Tree Street, N.E., Atlanta, Ga. 30323.
(*d*) Theoretical and laboratory investigation; basic research.
(*e*) Determine the motion pattern, both mean and turbulent, near the boundary between a larger main channel and a smaller overflow channel, for a fully established uniform state of motion.
(*g*) The experimental channel consists of a 12" x 12" main channel section and a 4" x 8" overbank section. The flow medium is air. Mean flow measurements are made with Pitot tubes in conjunction with well piezometers, and with hot-wire probes. Measurement of turbulent components of flow are made with hot-wire probes.
(*h*) **Turbulent Flow in a Rough Conduit,** H. J. Tracy, in preparation.

332-05607-060-00

EVALUATION OF DEPENDENT AND INDEPENDENT VARIABLES IN OPEN CHANNEL FLOW

(*c*) C. F. Nordin, U.S. Geol. Survey, ERC, CSU Foothills, Fort Collins, Colo. 80521.
(*d*) Experimental; basic research.
(*e*) Identify and evaluate the dependency characteristics of flow and sediment measures of alluvial channel flow. The experiments are designed to determine mean flow parameters and channel adjustments when bed material is an independent variable; determine the importance of depth as a scale parameter and as a driving force; determine the time for change when an independent variable is changed; and determine the variance of slope, depth, velocity, sediment transport, and bed conditions in time and space.
(*g*) The series of unique experiments with single radioactive particles of high activity showed that the particle step lengths were gamma distributed, the particle rest periods followed the exponential distribution, and the parameters of the distributions were related to flow conditions. The bed form lengths were gamma distributed with the relation most evident for the dune bed forms. Observations during the experiments suggested that most deposition and erosion occur below the mean bed elevation.
(*h*) **Motion of Single Particles in Alluvial Channels,** N. S. Grigg, *Proc. ASCE* **96,** HY12, 2501-2518, 1970.
Vertical Transfer in Open Channel Flow, H. E. Jobson, W. W. Sayre, *Proc. ASCE* **96,** HY3, 703-724, 1970.
Prediction Concentration Profiles in Open Channels, H. E. Jobson, W. W. Sayre, *Proc. ASCE* **96,** HY10, 1983-1996, 1970.
Discussion of **Motion of Single Particles in Alluvial Channels,** N. S. Grigg, H. E. Jobson, C. F. Nordin, Jr., *Proc. ASCE* **97,** HY9, 1541-1544, 1971.
Statistical Properties of Dune Profiles, C. F. Nordin, Jr., *U.S. Geol. Survey Prof. Paper 562-F*, 41 p., 1971.
Erosion and Sedimentation, C. F. Nordin, Jr., *Am. Geophys. Union Trans.* **52,** 6, 292-295, 1971.
Applications of Crossing Theory in Hydrology, C. F. Nordin, Jr., D. M. Rosbjerg, *Intl. Assoc. Sci. Hydrol. Bull.* **15,** 1, 27-43, 1970.
Tracer Studies of Sediment Transport Processes, C. F. Nordin, Jr., R. E. Rathbun, *Proc. ASCE* **97,** HY9, 1305-1329, 1971.

332-05610-200-00

MECHANICS OF FLOW STRUCTURE AND FLUID RESISTANCE–MOVABLE BOUNDARY

(*c*) R. S. McQuivey, U.S. Geol. Survey, Engrg. Res. Ctr., Foothills Campus, Colo. State Univ., Fort Collins, Colo. 80521.
(*d*) Experimental, theoretical and field investigation; basic research.
(*e*) Measure the internal flow field of turbulent shear flow in an open channel in order to obtain a fundamental understanding of the mechanics of fluid resistance. Further knowledge of the mechanics of flow structure will give a better understanding of the phenomena of energy dissipation, velocity distribution, shear distribution and the transport and dispersion of solutes and sediment.
(*g*) Turbulence characteristics were obtained with the hot-film anemometer in the 8-foot wide flume over an alluvial boundary, the Rio Grande conveyance channel, the Columbia River, the Missouri River, and the Mississippi River. Point sediment samples were collected at the point where the turbulence measurements were taken. The analysis of this data has been completed and interpretation of the data is continuing.
Open Channnel Flow Turbulence Measurements With a Propeller Flow Meter and a Hot-Film Anemometer, J. P. Bennett, R. S. McQuivey, *U.S. Geol. Survey Prof. Paper 700-B*, 1970.
Suspended Load, *Inst. of River Mechanics*, Colo. State Univ., June 1970.

332-05841-820-00

DENVER MULTIPHASE FLOW

(*c*) E. P. Weeks, U.S. Geol. Surv., Denver Federal Ctr., Denver, Colo. 80225.
(*d*) Theoretical and field investigation.
(*e*) Devise and test methods of measuring flow in, and hydraulic properties of, the unsaturated zone in the field. Measure velocities of fluids underground by analysis of temperature profiles. Develop and test methods of predicting the nature of flow in the unsaturated zone. Improve, and develop new techniques for field measurement of evapotranspiration.
(*g*) Measurements of the time lag and attenuation of fluctuations in gas pressure due to barometric changes as functions of depth below the land surface were made in the unsaturated zone near Cuba, New Mexico, for determining permeability of the unsaturated zone.
Although the field tests were successful, improvement in the instrumentation adopted is indicated. Type curves for analyzing drawdowns observed in well fields having variable discharge at scattered locations were developed for the New Mexico groundwater district through the Geological Survey Computations Unit. The computer program evolved is available for calculating the hydraulic properties of aquifers in areas where intensive use of groundwater is monitored at observation wells. Underground temperature profiles were observed in the field near Globe, Arizona and Roswell, New Mexico to test the possibility of using the temperature profile for indicating vertical velocities of groundwater through beds having low permeability. Indications are that vertical velocities as small as 0.1 foot per year can be identified by analysis of the steady-state temperature profile observed in beds about 100 feet or more in thickness.
The relation between losses from groundwater and evapotranspiration is being studied with the aid of the field offices of the Water Resources Division, U.S. Geological Survey, in Colorado. Measurements of groundwater levels, soil moisture tension and content, and temperature are being made at four 25 acre sites in the Arkansas River Valley. Lateral contribution to groundwater loss, due to spatial changes in flow through the aquifer, is monitored by finite-difference analysis of the shape of the water table. Project interest lies in testing of field techniques of measuring the hydraulic properties of the unsaturated zone, and defining the relation between evapotranspiration and depth to the water table. Field installations were completed in May 1965, and rebuilt by October 1965 after destruction by floods.

517-020 O-LT - 74 - 14

(*h*) **A Method to Describe the Flow of Radioactive Ions in Groundwater,** D. B. Grove, *Sandia Laboratories Rept. SC-70-6139*, 41 p., 1970, available NTIS, Springfield, Va. 22151.

Fluid Travel Time Between a Recharging and Discharging Well Pair in an Aquifer Having a Uniform Regional Flow Field, D. B. Grove, W. A. Beetem, and Sower, *Water Resour. Res.* **6,** 5, 1404-1410, 1970.

U.S. Geological Survey Tracer Study, Amargosa Desert, Nye County, Nevada; Part II: **An Analysis of the Flow Field of a Discharging-Recharging Pair of Wells,** D. B. Grove, *U.S. Geol. Survey Rept. USGS-474-99*, 56 p., 1971, available from NTIS, Springfield, Va. 22151.

Porosity and Dispersion Constant Calculations for a Fractured Carbonate Aquifer Using the Two-Well Tracer Method, D. B. Grove, and W. A. Beetem, *Water Resour. Res.* **7,** 1, 128-134, 1971.

332-06069-220-00

GRAIN SIZE DISTRIBUTION AND BEDLOAD TRANSPORT

(*c*) G. P. Williams.
(*d*) Basic research.
(*e*) Experimental flume studies relating bedload transport rate to various channel factors, and especially variations resulting from changes in size distribution keeping median grain size constant.
(*h*) **Flume Experiments on the Transport of a Coarse Sand,** *U.S. Geol. Survey Prof. Paper 562-B*, Sept. 1967.

Aids in Designing Laboratory Flumes: G. P. Williams, *USGS Open-File Report*, 294 pp., 1971.

332-06071-200-00

REAERATION IN OPEN CHANNEL FLOW

(*c*) R. E. Rathbun, U.S. Geological Survey, ERC, CSU Foothills, Fort Collins, Colo. 80521.
(*d*) Experimental; basic research.
(*e*) Investigation of processes by which dissolved oxygen is assimilated by flowing water in an open channel, and to develop improved criteria for predicting rate of assimilation as a function of flow, channel, and other measurable environmental characteristics.
(*g*) A consideration of the temperature dependence of the reaeration coefficient showed that all previously reported experimental values of the temperature coefficient lie between the theoretical temperature coefficient values for the two limiting forms of the film-penetration model of Dobbins.
(*h*) **Reaeration in Open Channel Flows,** J. P. Bennett, R. E. Rathbun, *USGS Open-File Report*, 314 pp., 1971.

A Convolution Approach to the Solution for Dissolved Oxygen Distribution in a Stream, *Water Resour. Res.* **7,** 3, 580-590, 1971.

332-08479-700-00

DISCHARGE MEASUREMENTS IN CONDUITS

(*c*) Mr. Jacob Davidian, Acting Chief, Hydraulics Section (SW), U.S. Geological Survey (WRD), Washington, D.C. 20242.
(*d*) Experimental; applied research.
(*e*) A metering device is sought, that will be easy to fabricate, easy to install in existing sewer pipes, and easy to service and monitor for both open-channel flows and pressure flows. It should be self-flushing, and maintain a standard rating. Various geometries of Venturi-type, self-flushing constructions of the full-pipe perimeter will be tested in model sizes. The most promising of these will be laboratory tested in prototype-size pipes. Ratings will be developed for the metering devices, and monitoring techniques and instrumentation will be developed.
(*g*) Four different construction shapes have been tested in a circular pipe. One shape has been tested in a six-inch plastic pipe and in a ten-inch aluminum pipe.

332-08480-140-00

DISSIPATION AND TRANSPORT OF HEAT IN SURFACE WATER

(*c*) Dr. Nobuhiro Yotsukura, U.S. Geological Survey, WRD, 220 Washington Building, Arlington Towers, Arlington, Va. 22209.
(*d*) Theoretical and experimental research aimed at temperature distribution in streams, lakes, and estuaries.
(*e*) The models are deterministic models which combine the convective diffusion equation of heat in water with the heat dissipation equation at air-water interface. The prediction of thermal pollution downstream from heat sources such as power plant effluents is one of the main applications.
(*g*) A model for unstratified streams with steady discharge was completed and tested by data from several streams including the Potomac River. It was found that the model can predict highly nonuniform temperature distribution within ±1℃.; the optimum transverse diffusion coefficient is 0.6 times shear velocity times depth; the heat dissipation coefficient varies from 0.02 to 0.10 foot per hour.
(*h*) **A Note on the Approximation of Heat Exchange at Air-Water Interface,** Yotsukura, Jackman, Faust. Completed for Water Resources Research, AGU. A report on the model study mentioned in item (g) is under preparation.

332-08481-740-00

NUMERICAL SIMULATION OF HYDRODYNAMIC PHENOMENA

(*c*) Dr. Chintu Lai, U.S. Geological Survey, 220 Washington Building, Arlington Towers, Arlington, Va. 22209.
(*d*) Theoretical investigations with field applications; basic and applied research.
(*e*) Develop numerical methods for solving selected surface and groundwater fluid-dynamic problems for which, hitherto, no tractable analytical solutions have been available; to develop new computer simulation techniques with which to model natural hydraulic and hydrologic phenomena in the prototype scale; and to devise accurate, informative, and economical *numerical experiments* into various unsolved hydrodynamic problems associated with the work of the Water Resources Division.
(*g*) Computer programs are written to simulate the movement of waves generated by flood or induced by tides. A few flow problems, both hypothetical and actual, have been successfully simulated. Digital models for time-of-travel study were made and applied to some channels. In such models, the investigator can inject index particles (or markers) into the channel at desired key points at different times, and perform the visual tracing of the particle movement. A computer animated movie was made to portray the movements of the tide waves and injected particles. As an advanced stage of one-dimensional models, a comprehensive program set to simulate unsteady flows in a compound-complex waterway system was composed and debugged. The making of a computer simulation model for two-space-dimensional unsteady flows in shallow water was then started and much progress has been made since. The programming using the method of characteristics was finished and some test runs with a few hypothetical bays have shown interesting and promising results.
(*h*) **Numerical Simulation of Wave-crest Movement in Rivers and Estuaries,** Chintu Lai, *The Use of Analog and Digital Computers in Hydrology, IASH/AIHS-UNESCO, Pub. No. 81 AIHS* **II,** 699-713, 1968.

A Computer Simulation Study of Traveltimes of Injected Particles and Tide Waves in Well-mixed Estuaries, Chintu Lai, *XIIIth Cong. Intl. Assoc. for Hydraulic Res. Proc.* **3,** 123-130, 1969.

Evaluation of Flow in Tidal Reaches of the Connecticut River by Mathematical Model, Chintu Lai, F. H. Ruggles, L. A. Lawrence, *Open-File Report, U.S. Geol. Survey*, 38 pages.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, LANGLEY RESEARCH CENTER, Langley Station, Hampton, Va. 23365. Edgar M. Cortright, Director.

333-06654-540-00

WATER LANDING IMPACT OF SPACECRAFT AND AIRCRAFT

(*c*) Mr. Lloyd J. Fisher, Assistant Head, Dynamic Loads Branch, Mail Stop 230.
(*d*) Experimental and analytical applied research.
(*e*) Experimental landing impact investigations are made with scaled dynamic models. Various landing attitudes, speeds, and body configurations are simulated. Hydrodynamic force and pressure distribution data on either relatively rigid or partially elastic models are obtained for comparison with theory. Specific energy dissipation capabilities are determined for various impact systems and materials using structural testing procedures and drop model techniques.
(*f*) Stand-by basis.
(*g*) See (h).
(*h*) **Ditching Investigation of a 1/30-Scale Dynamic Model of a Heavy Jet Transport Airplane,** W. C. Thompson, *NASA TM X-2445*, Feb. 1972, available from the Scientific and Tech. Information Div., NASA, Washington, D.C. 20546.

333-08482-540-00

STUDY OF RING BAFFLE PRESSURE DISTRIBUTION AND SLOSH DAMPING

(*c*) Harland F. Scholl, Engrg. Technician, Environmental Dynamics Section, Dynamic Loads Branch, Mail Stop 230.
(*d*) Experimental, analytical, applied research.
(*e*) Determine liquid pressure loads both radially and circumferentially on rigid ring baffles in large scale tests and to define damping values of both single and multiple ring baffles.
(*f*) Completed.
(*g*) Experimental results agree quite well with analysis which indicates the pressure distribution decreases from the wall to the tip of the baffle and circumferentially from the antinode to node location. The addition of a second baffle only slightly affected the magnitude of the pressures. The use of multiple baffles does not substantially increase the damping efficiency over that offered by a single baffle.
(*h*) **Ring Baffle Pressure Distribution and Slosh Damping in Large Cylindrical Tanks,** H. F. Scholl, D. G. Stephens, TN in preparation.

333-08483-540-00

DYNAMICS OF AIRCRAFT HYDRAULIC SYSTEMS

(*c*) Mr. James T. Howlett, Mail Stop 245.
(*d*) Analytical and experimental, applied research.
(*e*) Develop complete digital computer simulation of the functioning of aircraft hydraulic systems, including vibrations induced by structure-fluid interactions.
(*g*) Finite element computer programs have been shown to yield valid results in the analysis of coupled structure-fluid interactions in hydraulic lines.
(*h*) **Applications of NASTRAN to Coupled Structures and Hydrodynamic Responses in Aircraft Hydraulic Systems,** J. T. Howlett, *NASA TM X-2378* **1,** 407-419.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, LEWIS RESEARCH CENTER, 21000 Brookpark Road, Cleveland, Ohio 44135. Bruce T. Lundin, Director.

334-06342-700-00

LIQUEFIED-GAS FLOW MEASUREMENT

(*c*) Isidore Warshawsky, Chief, Instrument Research Branch.
(*d*) Experimental basic research.
(*e*) The program consists of development, test, and evaluation of techniques and equipment for accurately measuring the flow of liquefied gases, with particularly strong emphasis on liquid hydrogen.
(*g*) Small turbine-type meters of proper design for liquid hydrogen have been found to yield inaccuracies of less than 0.5 percent, when the meter is actually calibrated in liquid hydrogen.
(*h*) **NASA TM X-52984,** preprint of paper presented *1971 Symposium on Flow, Its Measurement and Control in Science and Industry.*

334-06344-620-00

HYDRODYNAMIC JOURNAL BEARING PERFORMANCE IN WATER AND LIQUID SODIUM

(*c*) William J. Anderson, MS 23-2, Chief, Bearings and Mechanical Power Transfer Branch, Fluid System Components Division.
(*d*) Experimental and theoretical applied research.
(*e*) Investigations of the stability characteristics of tilting pad, herringbone, lobed and stepped journal bearing configurations are being carried out. Analyses of lobed and stepped bearings are being made and experiments are being conducted with all of these bearing types in water at high speeds and low loads.
(*g*) Stability experiments have been conducted in water at zero applied load and speeds to 12,000 rpm. A plain bearing run with a three-tilted-lobe journal was more stable than a three-centrally-lobed journal. The incorporation of axial grooves in a tilted-lobe journal generally enhances its stability. The tilted lobe journals mated with plain bearings were unique in that, in some tests, the bearings could be run to a shaft speed twice the shaft speed at which initial fractional frequency whirl occurred before any sign of bearing distress was observed. From this study, thus far, five fixed-geometry bearings considered can be generally rated in order of diminishing stability as follows: (1) three-tilted lobe bearing (offset factor of 1.0), (2) herringbone-groove bearing, (3) one-segment, three-pad, shrouded Rayleigh-step bearing, (4) three-tilted lobe journal with grooves (offset factor of 1.0) mated with a plain bearing, and (5) three-centrally-lobed bearing with grooves (offset factor of 0.5).
(*h*) **Experiments on the Stability of Water-Lubricated Rayleigh Step Hydrodynamic Journal Bearings at Zero Load,** F. T. Schuller, *NASA TN D-6514*, 1971.
Experiments on the Stability of Water-Lubricated Three-Lobe Hydrodynamic Journal Bearings at Zero Load, F. T. Schuller, *NASA TN D-6315*, 1971.
Experiments on the Stability of Water-Lubricated Three-Sector Hydrodynamic Journal Bearings at Zero Load, F. T. Schuller, W. J. Anderson, *NASA TN D-5752*, 1970.
Experiments on the Stability of Water-Lubricated Three-Lobe Journals Mated With Plain Bearings at Zero Load, F. T. Schuller (TN in progress).
Experiments on the Stability of Various Water-Lubricated Fixed Geometry Hydrodynamic Journal Bearings at Zero Load, F. T. Schuller, *NASA TM X-68014*, 1972.

334-07040-630-00

COMPENDIUM ON THE DESIGN OF TURBOPUMPS AND RELATED MACHINERY

(*c*) Cavour H. Hauser, MS 5-9, Head, Single Stage Compressor Section, Fluid System Components Division.
(*d*) Exposition of theoretical and applied research.
(*e*) Compile pertinent information on turbopumps developed by NASA, the various contract research and development programs, and inhouse research. This information will be correlated and considered in proper perspective to provide a coherent presentation of the important principles of turbomachinery design. The Compendium will be published as a NASA Special Publication.
(*g*) Writing of the Compendium is continuing. Drafts of the first three of the seven planned chapters have been submitted.

334-08484-210-00

ANALYSIS OF EFFECT OF RANDOMLY FLUCTUATING PRESSURE GRADIENT ON FLOW IN CHANNELS

(*c*) Morris Perlmutter, Aerospace Engineer.
(*d*) Theoretical, applied research.
(*e*) Effect of randomly fluctuating pressure gradient on channel flow is analyzed numerically and analytically for power spectrums, amplitude distribution, system function and system power loss. Purpose of the study is to understand and control pressure fluctuations, power loss and noise generation in randomly fluctuating flow systems.
(*g*) Results for the incompressible flow case have been completed and published. Velocity fluctuation amplitude and system power loss increases with amplitude of pressure fluctuations. The higher frequency pressure fluctuations have a small effect on velocity fluctuations and sytem power loss.
(*h*) **Randomly Fluctuating Flow in a Channel Due to Randomly Fluctuating Pressure Gradients,** M. Perlmutter, *NASA TN D-6213*, Mar. 1971.
Effect of Randomly Fluctuating Pressure Gradients with Arbitrarily Specified Power Spectrums and Probability Density on Flow in Channels, M. Perlmutter, *NASA TM X-67881*, Oct. 1971.

334-08485-710-00

NUMERICAL FLOW VISUALIZATION

(*c*) Leo F. Donovan, Aerospace Engineer.
(*d*) Numerical, applied research.
(*e*) Development of a technique to show clearly the results of the numerical solutions of the Navier–Stokes equations. Velocities of special marked particles that move with the fluid are determined from the results of solution of the Navier–Stokes equations. Representations of these particles are displayed on a cathode ray tube and photographed with a microfilm recorder at each time step in the calculation. The resulting motion picture shows the movement of the fluid.
(*g*) A motion picture describing this work is available.
(*h*) **Computer–Generated Flow Visualization Motion Pictures,** L. F. Donovan, *Lewis Motion Picture C-271.*

334-08486-000-00

FLOW BETWEEN PARALLEL PLATES

(*c*) Leo F. Donovan, Aerospace Engineer.
(*d*) Numerical, applied research.
(*e*) Development of numerical technique for studying time-dependent fluid behavior by solving the Navier–Stokes equations.
(*g*) Work is in progress on investigating the effects of various inlet and outlet boundary conditions.

334-08487-000-00

FLOW IN A RECTANGULAR CAVITY WITH A MOVING WALL

(*c*) Leo F. Donovan, Aerospace Engineer.
(*d*) Numerical, applied research.
(*e*) Development of numerical technique for studying time-dependent fluid behavior by solving the Navier–Stokes equations.
(*f*) Complete.
(*g*) Study was conducted for Reynolds numbers from 100 to 500 for cavities of aspect ratios of 1/2, 1, and 2. Velocity profiles at large times agreed with those obtained from independent numerical solutions of the steady Navier–Stokes equations. Final positions of the vortex centers determined from the numerical solutions were close to those determined experimentally.
(*h*) Numerical Solution of the Unsteady Navier–Stokes Equations and Application to Flow in a Rectangular Cavity with a Moving Wall, L. F. Donovan, *NASA TN D-6312*, Apr. 1971.

334-08488-440-00

WIND-DRIVEN CURRENTS IN LAKE ERIE

(*b*) Joint laboratory and Case Western Reserve University project.
(*c*) Richard T. Gedney, Head, Analytical Section of the Fluid Mechanics and Thermal Sciences Branch.
(*d*) Numerical, applied research; Doctoral thesis.
(*e*) The steady-state, wind-driven three-dimensional velocities are calculated numerically for Lake Erie using a shallow lake model. The Lake Erie boundary geometry and bottom topography are incorporated in considerable detail using over 5000 horizontal grid points. From the solution the local velocity can be determined at any horizontal and vertical position in the lake. The results are being used in dispersion studies of pollutants.
(*f*) Complete.
(*g*) The results show that the velocities are very dependent on the lake's boundary geometry and bottom topography. Agreement between current meter measurements and calculations is very good.
(*h*) **Numerical Calculations of the Wind-Driven Currents in Lake Erie,** T. T. Gedney, *Ph.D. Thesis*, Case Western Reserve University, Cleveland, Ohio, 1971.
Numerical Calculations of the Wind-Driven Currents in Lake Erie and Comparison With Measurements, R.T. Gedney, W. Lick, *Proc. 14th Great Lakes Res. Conf., Intl. Assoc. Great Lakes Res.*, 1972.

334-08489-540-00

GAS JET IMPINGEMENT ON LIQUID SURFACES AT NORMAL AND REDUCED GRAVITY

(*c*) Donald A. Petrash, Chief, Gravitational Effects Branch.
(*d*) Experimental; applied research.
(*e*) Investigate the effect of gravitational environment on the behavior of a liquid surface during gas jet impingement in order to predict gas penetration, spraying, free bubble motion in the liquid, and gas blowthrough.
(*f*) Completed.
(*g*) Experimental investigations were conducted in which the characteristics were determined for gaseous jets impinging normally on liquid surfaces in regions where both gravitational and surface tension forces were significant. The critical gas jet velocity for cavity stability was correlated with Weber and Reynolds numbers for water in a weightless environment. Surface penetration depths of a laminar gas jet impinging normally on liquid surfaces were correlated for ar initially parabolic gas-jet velocity profile in terms of Weber and Bond numbers. Included are qualitative observations concerning cavity shape, bubble pinch-off, and, for cases of large gas-jet momentums, cavity growth.
(*h*) **Gas Jet Impingement on Liquid Surfaces During Weightlessness,** T. L. Labus, *NASA TN D-5720*, Mar. 1970.
Cavity Stability During Gas Jet Impingement on Liquid Surfaces in Weightlessness, T. L. Labus, *NASA TN D-5976*, Sept. 1970.
Gas Jet Impingement Normal to a Liquid Surface, T. L. Labus, J. C. Aydelott, *NASA TN D-6368*, May 1971.

334-08490-540-00

PRESSURIZED DISCHARGE OF LIQUID PROPELLANTS FROM STORAGE TANKS

(*c*) Philip A. Masters, Aerospace Engineer.
(*d*) Theoretical and experimental applied research.
(*e*) Two separate computer programs, coded in Fortran IV, are available for the pre-pressurization and for the pressurized expulsion of a cryogenic liquid from an axisymmetric storage vessel. Each program may be used independently to predict pressurant gas requirements as well as the ullage gas temperature and adjacent wall temperature distribution. Use of the analytical programs does not

require preliminary experimental data, or any knowledge of system parameters. Only requirements are gas transport property data and specific heat data which may be easily substituted into the appropriate subroutines for each case studied. A complete description of the required input and format is provided on comment cards with the card decks. Verification of the analysis was conducted for a range of outflow rates and nominal pressures in cryogenic environments.

(*f*) Completed and operational.

(*g*) Good experimental comparative data were obtained for gas injectors that tend to distribute the pressurant gas uniformly across the liquid interface. Inlet gas temeperature, gas molecular weight, and heat transfer characteristics influence the pressurant gas requirements. The validity of this one-dimensional analysis has been verified for a range of cylindrical and spheroidal tanks (5 ft-13 ft diam.).

(*h*) **Gaseous-Hydrogen Requirements for the Discharge of Liquid Hydrogen from A 1.52 Meter Diameter Spherical Tank,** R. J. Stochl, P. A. Masters, R. L. DeWitt, J. E. Maloy, *NASA TN D-5336*, Aug. 1969.

Gaseous-Hydrogen Pressurant Requirements for the Discharge of Liquid Hydrogen from a 3.96 Meter (13-FT) Diameter Spherical Tank, R. J. Stochl, P. A. Masters, R. L. DeWitt, J. E. Maloy, *NASA TN D-5387*, Aug. 1969.

Gaseous-Helium Requirements for the Discharge of Liquid Hydrogen from a 1.52 Meter Diameter Spherical Tank, R. J. Stochl, J. E. Maloy, P. A. Masters, R. L. DeWitt, *NASA TND-5621*, Jan. 1970.

Gaseous-Helium Requirements For The Discharge of Liquid Hydrogen from a 3.96 Meter Diameter Spherical Tank, R. J. Stochl, J. E. Maloy, P. A. Masters, R. L. DeWitt, *NASA TN D-7019*, Dec. 1970.

(Available from NASA Scientific and Technical Information Facility, College Park, Md.)

UNITED STATES NAVAL ACADEMY, DEPARTMENT OF THE NAVY, Division of Engineering and Weapons, Annapolis, Md. 21402. Captain P. W. Nelson, Director.

335-06131-000-20

A MATHEMATICAL MODEL OF A FORCED VORTEX

(*b*) Office of Naval Research.

(*c*) Dr. Robert Granger, Professor.

(*d*) Theoretical and experimental research.

(*e*) A mathematical model of an incompressible steady three-dimensional viscous vortex flow of arbitrary injection flow rate, fluid column height, sink orifice geometry and viscosity is found and compares within 10 percent of experimental results of velocity field, vorticity, core radius and circulation.

(*f*) Completed.

(*h*) *Geophysical Fluid Dynamics* 3.

335-07046-720-22

THE DESIGN OF A HIGH PERFORMANCE TOWING TANK

(*b*) Laboratory project/NavShipSysCom.

(*c*) Dr. Bruce Johnson, Director, Hydromechanics Laboratory.

(*d*) Design of a new facility.

(*e*) The conceptual design of a 380 ft by 26 ft by 16 ft towing tank capable of speeds up to 50 feet per second was investigated. The tank will be part of the new Engineering Studies Complex at the Naval Academy and is being designed to support Naval Architecture, Ocean Engineering and Oceanography studies, as well as research in flow-induced noise and general hydrodynamics.

(*f*) Both preliminary and engineering design of the towing carriages are complete. Construction contract on both basin and carriages is underway. Design of wavemakers, controllers, and data acquisition equipment is underway.

(*h*) **Design Summary of the USNA 380 Foot High Performance Towing Tank,** F. J. Schroeder, B. Johnson, reported in *Div. of Engrg. and Weapons Repts., E-71-2*.

Design Summary of Data Acquisition and Analysis Systems for the 380 Foot High Performance Towing Tank, E. A. Laufer, B. Johnson, reported in *Div. of Engrg. and Weapons Repts., E-71-3*, presented at the 16th Amer. Towing Tank Conf., Sao Paulo, Brazil, Aug. 1971.

335-07050-000-21

ON THE FEEDING OF FORCED VORTEX FLOWS

(*b*) Naval Ship Research and Development Center.

(*c*) Dr. Robert Granger, Professor.

(*d*) Experimental.

(*e*) Experimental investigation in how a vortex is fed, and the origin and mechanism of reversed axial flow in the flow field.

(*f*) Completed.

335-08491-870-20

AIR POLLUTION CONTROL WITH VORTICES

(*b*) Office of Naval Research, Naval Academy Research Council.

(*c*) Dr. Robert Granger, Professor.

(*d*) Experimental.

(*e*) Experimental investigation into isolating particulates in smoke stacks by use of vortex dynamics.

335-08492-520-20

MATHEMATICAL MODEL FOR THE DEVELOPMENT OF A CONSTANT DEPTH FLUIDIC CONTROLLED SUBMERSIBLE VEHICLE

(*b*) Office of Naval Research.

(*c*) Chih Wu, Assoc. Professor.

(*d*) Basic research.

(*e*) Find a mathematical model that represents uniform potential incompressible steady flow over a two-dimensional blunt body that has mass flow injected into the main flow at a predetermined location on the body geometry.

(*f*) Completed.

(*g*) A suitable mathematical model of a towed vehicle to operate automatically at constant depth can be designed.

(*h*) *USNA Engineering Report E-70.*

335-08493-590-48

A STUDY OF NAVIGATION BUOY CONFIGURATION

(*b*) U.S. Coast Guard.

(*c*) Professors Joseph Sladky, Michael McCormick, Rameswar Bhattacharyya.

(*d*) Experimental and theoretical.

(*e*) New buoy configurations are being studied in a wave and towing tank. The motions of the buoy models and their prototypes are being analyzed using the strip theory.

(*g*) Two by-products have thus far resulted from this study. First, a method for fabricating models of any shape which requires a minimum amount of time; second, an optical system for measuring model motions.

335-08494-420-20

TIME-DEPENDENT SHEAR STRESS BENEATH A SHOALING WAVE

(*b*) Office of Naval Research.

(*c*) Mdm. J. W. Fisher, Dr. Bruce Johnson, Dr. Michael McCormick.

(*d*) Experimental.

(*e*) An experimental study of the time-dependent characteristics in shoaling waves using hot-film anemometers and a real time analysis computer system. The fluctuating shear stress is measured using flush-mounted hot-films.

335-08495-130-20

COMPUTER STUDIES ON THE EVOLUTION OF WATER VAPOR CLUSTERS

(*b*) Office of Naval Research.
(*c*) Andrew A. Pouring, Professor.
(*d*) Experimental and basic research.
(*e*) In order to verify a new kinetic theory of cluster formation, numerical techniques have been developed to evaluate equilibrium and non-equilibrium solutions applicable to rapid expansion in supersonic nozzles.
(*g*) A method of determining the cluster size at which macroscopic properties become relevant has been found. Water vapor properties are calculated and collision diameters satisfying conditions of detailed balance are determined.

NAVAL CIVIL ENGINEERING LABORATORY, DEPARTMENT OF THE NAVY, Port Hueneme, Calif. 93043. Technical Director, Code L03.

336-07052-430-00

EFFECT OF NUCLEAR EXPLOSIONS ON DEEP OCEAN STRUCTURES

(*d*) Theoretical, applied research.
(*e*) The response of elastically-restrained, rigid, spherical and cylindrical structures to weak underwater shock waves is being studied. This is a preliminary study for the purpose of developing criteria for the design of hardened deep ocean structures.
(*g*) The response to exponentially attenuated shock waves has been obtained through the use of linear acoustic theory and Fourier transform methods. For a spherical structure, the Fourier transform of the structure's response was obtained exactly. For a cylindrical structure, a numerical procedure was required; the numerical method was tested on the spherical problem and found to be adequate.
(*h*) **Comparative Solution for the Response of Restrained Rigid-Body Underwater Structures to Acoustic Shock,** J. G. Hammer, H. S. Zwibel, *Naval Civil Engrg. Lab., Tech. Note No. N-1141*, 73 pages, Jan. 1972 (available NTIS, Springfield, Va. 22151).

336-08496-600-22

DEVICE FOR MIXING TWO FLUIDS FOR SPECIALIZED NAVAL APPLICATIONS

(*b*) Director of Navy Laboratories.
(*c*) Mr. D. Pal, Project Engineer, Mechanical Systems Division, Code L63.
(*d*) Experimental; applied research.
(*e*) Develop a proportional fluid amplifier system for mixing fluids for applications where shock resistant rapid response and low maintenance are required, such as in Navy diving operations.
(*g*) The mixing system uses two proportional fluid amplifiers of the double-leg elbow type, one for each fluid. Major effort is being spent in developing a modified double-leg elbow amplifier capable of modulating 5 gpm of water flow rates. Test results show that an amplifier of this type would perform as a good flow modulator only at moderate output impedence.
(*h*) **Fluidic Devices for Mixing Two Fluids-Feasibility Study,** D. Pal, *Naval Civil Engrg. Lab., Tech. Note N-1056*, 49 pages, Sept. 1969.
A Fluidic System for Mixing Two Fluids-Development Study, D. Pal, *Naval Civil Engrg. Lab., Tech. Note N-1150*, 24 pages, Feb. 1971.
Using Fluidics to Control Continuous Blending, D. Pal, *Instruments and Control Systems*, April 1972.

336-08497-430-00

HYDRAULIC MODEL STUDY OF MOBILE OCEAN BASING STATION

(*c*) Dr. Cheng L. Liu, Project Engineer, Ocean Structures Division, Code L44.
(*d*) Experimental; applied research.
(*e*) Hydraulic model studies were conducted in wave tanks to determine the effects of platform leg shape on resultant wave forces. Under certain wave conditions, a crescent cross-sectioned leg is expected to produce force opposite to direction of wave propagation.
(*f*) Completed.
(*g*) The crescent-shaped columns can provide a limited force in the direction of wave propagation when they are oriented with the convex side facing the approaching waves.
(*h*) **Wave Energy Extraction by Crescent Shaped Columns for Station Keeping of Floating Ocean Platforms-Hydraulic Model and Feasibility Study,** C. L. Liu, R. H. Fashbaugh, *Naval Civil Engrg. Lab., Tech. Note N-1156*, Mar. 1971.

336-08498-430-22

TRANSPORTABLE BREAKWATERS

(*b*) Naval Facilities Engineering Command.
(*c*) Director, Amphibious and Harbor Division, Code L55.
(*d*) Theoretical; applied research.
(*e*) Survey of concepts for a wave barrier, to identify those having potential application in a "transportable" (or "portable") breakwater; emphasis on wave transmission properties.
(*f*) More than 100 existing concepts were assembled into an outline classification of transportable breakwaters, based on type (form) of structure, with line drawings of cross sections and concise summaries of wave transmission data.
(*h*) **Transportable Breakwaters-A Survey of Concepts,** D. B. Jones, *Naval Civil Engrg. Lab., Tech. Rept. No. R-727*, 70 pages, May 1971 (available NTIS, Springfield, Va. 22151).

NAVAL COASTAL SYSTEMS LABORATORY, DEPARTMENT OF THE NAVY, Panama City, Fla. 32401. Captain L. O. G. Whaley, Commanding Officer.

337-06927-420-00

SHALLOW WATER WAVE RESEARCH

(*c*) Mr. G. G. Gould, Technical Director, Code 101.
(*d*) Experimental, theoretical, applied research, also Doctoral dissertation input, re; Columbia University, New York.
(*e*) A continuing investigation following earlier measurements of the variability of the shallow ocean wave phenomenon as gravity wave elements progress shoreward and seaward over a shoaling bottom between two offshore platforms has been conducted. Wave measurements were made using circular arrays of pressure sensors placed near the sea bed and solitary surface wave staff sensors at each of two offshore platforms. The ability to predict wave modification in the nearshore ocean is a goal of this continuing investigation. Fundamental tools employed in the studies include the high speed computer, modern statistical techniques for estimating power and cross power spectra and geometrical optics.
(*f*) The measurement effort has been discontinued, but theoretical work with the considerable store of wave data continues.
(*g*) Estimates of directional spectra for different boundary conditions of depth, sea state, surface wind time and distance have been mapped for a variety of wave conditions in the frequency band between 0.15 Hz to 0.005 Hz. Results include analytic techniques, refraction effects (basic new results), wave reflection, wave trapping for conditions of calm to those of hurricanes occurring in the Northeast Gulf of Mexico. A Doctoral dissertation of the

analytical results of much of this investigation has been submitted to the Lamont-Doherty Geological Laboratory, Columbia University, New York, for approval.

(*h*) **Snell's Law for a Narrow Frequency Continuum,** J. E. Breeding, Jr., (U.S. Navy) *Trans. AGU* **52,** 11, 1971 (Abstract).

Hydrons and Water Waves, J. E. Breeding, Jr., *Amer. J. Physics* **39,** 6, 1971, p. 712.

The Directional Analysis of Ocean Waves: An Introductory Discussion, C. M. Bennett, *U.S. Navy Rept. NSRDL/PC 3472*, Sept. 1971.

An Assay of Environmental Data Collected Off Panama City, Florida from 1962 to 1968, C. M. Bennett, F. C. W. Olson, *U.S. Navy Rept. No. NSRDL/PC 3444*, Mar. 1971.

Gravity Water Wave Refractions Using Group Velocity, K. C. Matson, *U.S. Navy Rept. No. NSRDL/PC 3132*, Aug. 1970.

Group Velocity and Hurricane Tracking, J. E. Breeding, Jr., *Trans. AGU* **51,** 11, 1970, p. 768 (Abstract).

A Theoretical Verification of Breeding's Conjecture, E. A. Hogge, F. C. W. Olson, *Trans. AGU* **51,** 11, 1970, p. 768.

The Significance of Wave Refraction According to Group Velocity, J. E. Breeding, Jr., *Proc. 7th Symp. on Military Oceanogray* **1,** Annapolis, Md., May 1970.

Group Velocity and Wave Refraction, J., E. Breeding, Jr., *Trans. AGU* **50,** 11, 1969, p. 631 (Abstract).

U.S. NAVAL OCEANOGRAPHIC OFFICE, Washington, D.C. 20390. Boyd E. Olson, Scientific and Technical Director.

338-06454-420-00

WAVE FORECASTING RESEARCH

(*c*) Mr. John J. Schule, Jr., Director, Research and Development Department (Code 70).

(*d*) Applied research involving field experiments with wind-generated ocean waves.

(*e*) Development of automated wave prediction techniques on an oceanwide basis including the North Atlantic Ocean, North Pacific Ocean, South China Sea, and Mediterranean Sea; observations of fetch-limited wave spectra with an airborne laser, shipboard observations of wave spectra with a bow-mounted wave sensor.

(*g*) Documentation of dependence of drag coefficient on atmospheric stability and surface wave background.

(*h*) **A Study of Fetch-Limited Wave Spectra with an Airborne Laser,** J. J. Schule, L. S. Simpson, P. S. DeLeonibus, *J. Geophys. Res.* **76,** 4160-4171, 1971.

Momentum Flux and Wave Spectra Observations from an Ocean Tower, P. S. DeLeonibus, *J. Geophys. Res.* **76,** 6506-6527, 1971.

A Study of Ocean Wave Spectra for Relation to Ships Bending Stresses, R. Guthrie, *Informal Rept. No. 71-12*, U.S. Naval Oceanographic Office, 1971.

A Case Study of Duration-Limited Wave Spectra Observed at an Open Ocean Tower, P. S. DeLeonibus, L. S. Simpson, submitted to *J. Geophys. Research.*

Observations of Wave Spectra in the Norwegian Sea with a Bow-Mounted Wave Height Sensor, P. S. DeLeonibus, J. Boogaard, R. J. Sheil, B. E. Olson, submitted to *J. Geophys. Research.*

NAVAL ORDNANCE LABORATORY, White Oak, Silver Spring, Md. 20910. Dr. G. K. Hartmann, Technical Director.

340-04867-510-22

HYDROBALLISTICS RESEARCH

(*b*) Naval Ordnance Systems Command.

(*c*) Dr. A. E. Seigel, Chief, Ballistics Department.

(*d*) Experimental, theoretical; basic and applied research.

(*e*) To study high-velocity water entry as related directly or indirectly to the behavior of missiles. The study includes the stability, pressures, and forces during the entry; cavity development and pressure; and the missile trajectory. A wide range of developmental and research configurations and of experimental conditions are investigated. The missiles are launched from gas or powder guns. A large tank facility was completed near the end of 1966 which was designed for use with large, high-speed missiles. This tank permits atmospheric pressure reduction and dense gas substitution for model scaling. A second, smaller tank supplements the large tank for smaller, lower-speed models. Both tanks are suited to such experimental projects as water entry, water exit, and trajectory studies. Current programs involve axial and oblique impact forces and pressure distributions on models, pressure in the water-entry cavity, and propulsion and stability of non-buoyant missiles.

(*g*) Results of recent studies include prediction of water entry drag coefficients for ogives from cone data; experimental determination of water entry cavity pressure; steady state drag coefficients of various cavitating head forms; measurements of the virtual mass of cones during entry and the effect of the air-water interface; the behavior of the water-entry cavity during formation and closure.

(*h*) **The Steady State Drag Coefficients of Various Cavitating Head Forms,** V. C. D. Dawson, A. E. Seigel, *NOLTR 70-206*, Oct. 1970.

Vertical Water Entry of Cones, J. L. Baldwin, *NOLTR 71-25*, Feb. 1971.

Vertical Water Entry of Some Ogives, Cones, and Cusps, J. L. Baldwin, *NOLTR 71-155*, Nov. 1971.

An Experimental Investigation of Means to Suppress the Flutter Motion of Elastically Suspended Cylinders Exposed to Uniform Cross Flow, J. Berezow, D. W. Sallet, *NOLTR 72-6*, Feb. 1972.

Dissipation of an Axially Symmetric Turbulent Wake in the Very Far Field, R. H. Waser, *NOLTR 72-26*, Dec. 1971.

U.S. NAVAL POSTGRADUATE SCHOOL, Department of Aeronautics, Monterey, Calif. 93940. Dr. R. W. Bell, Department Chairman.

341-06588-020-00

COMPUTER SIMULATION OF TURBULENCE

(*c*) Professor T. H. Gawain, Code 57Gn.

(*d*) Theoretical; basic research for Ph.D.

(*e*) The energy transfer from a shear flow to turbulence is being investigated, using a computer.

(*g*) A unified heuristic model of fluid turbulence has been developed which comprises a closed set of equations; only the boundary conditions change for different applications. Numerous eigenvalues and eigenfunctions of the Orr-Sommerfeld equations for plane Poiseuille flow have been systematically calculated. The nonlinear response of plane Poiseuille flow to disturbances of various wave numbers and amplitudes has been found by numerical integration of the equations of motion. A new method of analysis for such flows is under development, based on an expansion in terms of the eigenfunctions of the linearized problem.

(*h*) **A Unified Heuristic Model of Fluid Turbulence,** with J. W. Pritchett, *J. Computational Physics* **5,** 3, pp. 383-405, June 1970.

Development of a Unified Heuristic Model of Fluid Turbulence, with J. W. Pritchett, *Naval Postgraduate School Rept. NPS-57Gn71021A*, 119 pages, Feb. 1971.

Tables of Eigenvalues and Eigenfunctions of the Orr-Sommerfeld Equation for Plane Poiseuille Flows, with W. H. Clark, *Naval Postgraduate School Rept. NPS-57Gn71092A*, 184 pages, Sept. 1971.

A Numerical Investigation of Finite Amplitude Disturbances in a Plane Poiseuille Flow, G. D. O'Brien, *Ph.D. Dissertation*, Naval Postgraduate School, June 1970.

Numerical Simulation of Transition and Turbulence in Plane Poiseuille Flow, with G. D. O'Brien, *Proc. 2nd Intl. Conf. Numerical Methods in Fluid Dynamics*, Univ. of Calif., Berkeley, Springer-Verlag, pp. 308-313, Sept. 15-19, 1970.

Some Recent Developments in the Numerical Analysis and Simulation of Fluid Turbulence, *Proc. Workshop on Flow in Turbomachines*, Naval Postgraduate School, Monterey, Sect. 4, pp. 1-46, Dec. 1970.

A Numerical Investigation of the Nonlinear Mechanics of Wave Disturbances in Plane Poiseuille Flows, with W. H. Clark, *Naval Postgraduate School Rept. NPS-57Gn71901A*, 121 pages, Sept. 1071.

Numerical Studies of the Nonlinear Instability of Plane Poiseuille Flows, submitted *ASME Joint Conf. of Fluids Engrg. and Appl. Mech.*, Georgia Tech., Atlanta, Ga., June 20-22, 1973.

Reports available from DDC, Cameron Station, Alexandria, Va. 22314.

341-06589-040-00

UNSTEADY AERODYNAMICS

(*c*) L. V. Schmidt, Professor, Code 57Sx.
(*d*) Experimental and theoretical; basic research at Ph.D. level.
(*e*) Unsteady aerodynamics–separated and potential flow. Motion dependence in bluff body aerodynamics, pressure fields of low aspect ratio lifting surfaces, and body interference, utilizing low-cost transducer concept of Bergh which is ideally suited for aeroelastic models.

341-06882-700-22

HOLOGRAPHIC INTERFEROMETRY

(*b*) Naval Air Systems Command.
(*c*) Professor D. J. Collins, Code 57Co.
(*d*) Experimental and theoretical applied research.
(*e*) Application of Q switch holography to the determination of complex three-dimensional density field.
(*h*) **Determination of Three-Dimensional Density Fields from Holographic Interferograms,** R. D. Matulka, D. J. Collins, *J. Appl. Phys.* **42**, 3, Mar. 1971.
Holographic Determination of Simple Translation and Rotations, R. P. Floyd, D. J. Collins, *Amer. J. Physics* **39**, 4, 359-362, Apr. 1971.
Finite Fringe Holographic Interferometry Applied to a Right Circular Cone at Angle of Attack, R. C. Jagota, D. J. Collins, accepted for *J. Applied Mechanics*.

341-06883-010-15

HELICOPTER BLADE STALL

(*b*) Army Aeronautical Laboratories.
(*c*) J. A. Miller, Associate Professor, Code 57Mo.
(*d*) Experimental basic and applied research.
(*e*) Wind tunnel simulates harmonic variation in velocity stall of helicopter blades; measurements using pressure taps, tufts and hot-wire anemometers. Basic investigation of boundary layer response to oscillating free stream.
(*h*) **Heat Transfer in the Oscillating Turbulent Boundary Layer,** *J. Engrg. for Power, Trans. ASME* **91,** Series D, 4, 1969.
Separation in Oscillating Boundary Layer Flows, *J. Fluid Mech.* **47**, 21-31, 1971.
Heat Transfer to an Airfoil in Oscillating Flow, *J. of Engrg. for Power, Trans. ASME* **93**, pp. 461-468, 1971.
Non-Similar Solution of the Laminar Boundary Layer in an Oscillatory Flow by an Integral Matrix Method, *J. of Basic Engrg., Trans. ASME* **93**, pp. 543-549, 1971.

U.S. NAVAL POSTGRADUATE SCHOOL, Department of Mechanical Engineering, Monterey, Calif. 93940. Dr. R. H. Nunn, Department Chairman.

342-07056-600-14

A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF TURBULENT JETS IN BEAM-DEFLECTION AMPLIFIERS

(*b*) Army Research Office, Durham.
(*c*) T. Sarpkaya, Professor.
(*d*) Theoretical and experimental study of the velocity and turbulence distributions in the ineraction region of the jets. Basic research for M.S. and Ph.D. theses.
(*e*) Study jet pinching, resultant jet deflection, noise sources and distribution, the effects of setback and control-port width and Reynolds number on the amplifier gain, and the modeling laws.
(*g*) The study of the velocity and turbulence profiles in the interaction and flow-establishment region of three jets of unequal velocities has shown that the increase of the strengths of control jets (higher normalized average control flow) results in the pinching of the power jet, in nonlinearity of the jet deflection, and in lower noise and sensitivity; the deflection of the jet does not materially affect the noise level at a given axial distance larger than 4w; the minimum noise level is in the order of 5 percent due to the contributions of the jet interaction and flow entrainment and could be considerably higher at normal operating conditions due to several other factors such as aspect ratio, receiver shape, cavity oscillations, etc.; the noise level remains relatively low and constant in the jet-establishment region and increases almost linearly in the fully-developed region; all components of turbulence are of the same order of magnitude and must be taken into consideration in the determination of the noise level; in the design and operation of a proportional amplifier, one must not use a center dump, must capture the noise-free region of the jet, place the receivers as close as possible to the pivoting point, and use as low control flows as practically possible to achieve a given jet deflection; and that the design of a proportional amplifier may be confidently based on the results of the free-streamline theory carried out as part of the present investigation.
(*h*) **On Mean Motion, Jet Turbulence, and Noise in Proportional Amplifiers,** T. Sarpkaya, *Proc. Intl. Fed. Automatic Controls* **2,** pp. 1-7, Sec. A, June 1971.
Jet Deflection, Noise, etc., *Engineers Degree Thesis*, NPS, Sept. 1971.

342-07057-250-21

RESISTANCE TO THE FLOW OF DILUTE AQUEOUS POLYMER SOLUTIONS

(*b*) Naval Ship Research and Development Center.
(*c*) T. Sarpkaya, Professor.
(*d*) Theoretical and experimental study of the flow of second-order viscoelastic fluids and the lift and drag characteristics of hydrofoils immersed in dilute polymer (WSR-301) solutions. Ph.D. thesis.
(*e*) The effect of polymers on the lift and drag of hydrofoils is being studied through the use of a water tunnel.
(*g*) The flow of aqueous solutions of Polyox WSR-301, with concentrations to 1.0 to 200 wppm, about circular cylinders was investigated in the critical Reynolds number regime. The drag force, pressure distribution, separation angle, and the vortex shedding frequency were measured on cylinders with diameters 1/4 to 1-1/2 inch. Two distinct types of drag transition between the subcritical and supercritical regimes were observed. At high concentrations, the transition occurred at the same ambient velocity independent of the body diameter; and at low concentrations and/or in situ molecular weights, tripping from a subcritical to a supercritical flow occurred at a well-defined flow condition which was a function of the ambient velocity, cylinder size, and the turbulent friction-reducing effective-

ness of the solution in pipe rheometer. In all cases, transition occurred earlier than that in the pure solvent and was accompanied by a strong secondary flow in the separation region and relatively large amplitude pressure oscillations over the entire cylinder.

(*h*) **Flow of Dilute Polymer Solutions About Circular Cylinders,** T. Sarpkaya, P. G. Rainey, *NPS-59SL1021A*, Feb. 1971.
Flow of Dilute Polymer Solutions About Bluff Bodies, T. Sarpkaya, *Proc. Canad. Cong. Appl. Mech.*, pp. 627-628, June 1971.
Flow of Dilute Polymer Solutions About Bluff Bodies, P. G. Rainey, *Ph.D. Thesis*, NPS, Mar. 1971.
The Effect of Dilute Polymer Solution on the Strouhal Frequency of Circular Cylinders, R. E. Kell, *M.E. Engineer's Degree Thesis*, June 1971.

342-08499-530-21

FLOW OF DILUTE POLYMER SOLUTIONS ABOUT HYDROFOILS

(*b*) Naval Ship Research and Development Center.
(*c*) T. Sarpkaya, Professor.
(*d*) Theoretical and experimental determinations of the effect of polymer solutions on the lift and drag forces characteristic of hydrofoils.
(*e*) Hydrofoils are used for a wide variety of purposes such as propeller blades on boats, as sailboat keels, ship rudders, submarine and torpedo fins, lifting surfaces of hydrofoil boats, shroud ring stabilizers for missiles, rotor blades for water jet propulsion units, impeller blades in pumps, support struts, etc. These different applications have resulted in the development of a wide variety of hydrofoil forms and in an intensive search for the increase of lift primarily for the purpose of optimizing the lift and drag characteristics of the foil and the performance of the body to which it is attached. To this end, a series of measurements of the lift and drag forces acting on an uncambered, streamlined, fully-wetted hydrofoil (NACA-0024) immersed in homogeneous solutions of a high-molecular-weight additive (Polyox WSR-301) was carried out in a circulating water tunnel with a test section 4 inches wide and 8 inches deep.
(*g*) The comparison of the results with those obtained using tap water as the working fluid has shown that the polymer additive has no measurable effect on the lift and drag of the hydrofoil within the range of concentrations used (1 to 200 wppm) and the Reynolds numbers attained (approx: 2 x 10^5).
(*h*) **Flow of Dilute Polymer Solutions About Circular Cylinders,** T. Sarpkaya, P. G. Rainey, *NPS-59SL1021A*, Feb. 1971.
Flow of Dilute Polymer Solutions About Bluff Bodies, P. G. Rainey, *Ph.D. Thesis*, NPS, Mar. 1971.

342-08500-600-22

EVALUATION OF FLUIDIC CONCEPTS FOR GUIDANCE AND CONTROL

(*b*) Naval Air Systems Command.
(*c*) T. Sarpkaya, Professor.
(*d*) Experimental, theoretical, Master's thesis.
(*e*) Evaluation of advance control concepts utilizing fluidic systems.
(*g*) It is as a consequence of these studies that a new pneumatic vortex angular rate sensor has been conceived, designed, tested, and analyzed. The porous coupling, used in all other vortex rate gyros, was replaced by a series of vanes and viscous coupling and a new pickoff system comprised of two spherical elements was introduced. The experimentally determined differential-pressure outputs compared favorably well with those predicted theoretically. Furthermore, the elimination of the porous coupling, the use of vanes and viscous coupling, and more importantly, the use of spherical pickoff elements have resulted in the increase of the sensor output, in the decrease of noise, in the elimination of the null-signal, and in the increase of the range of linearity of the sensor.
(*h*) **On a New Vortex Angular Rate Sensor,** T. Sarpkaya, *Proc. Intl. Federation of Automatic Controls* 2, pp. 86-91, Sec. B, June 1971.
Of Fluid Mechanics and Fluidics and of Analysis and Physical Insight, presented at *5th Cranfield Fluidics Conf.*, Uppsala, Sweden, June 1972.

342-08501-600-22

FLUERIC LOW-FREQUENCY NOISE ANALYSIS

(*b*) Naval Air Systems Command.
(*c*) T. Sarpkaya, Professor.
(*d*) Experimental, theoretical, Master's thesis.
(*e*) An investigation of the noise characteristics of flueric devices especially of the jet deflection type.
(*g*) It has been found that the smaller aspect ratios show a much greater variation in percentage of turbulence with low power-jet pressures; at higher pressures, the percentage turbulence is approximately constant with pressure changes, for all aspect ratios tested; and the peak percentage turbulence increases with increasing aspect ratio. The results have also shown that an improved signal-to-noise ratio is not obtained without paying a price; in this case, a reduction in gain. The data show that the pressure gain is almost insensitive to power jet pressure but varies with aspect ratio. In particular, the gain falls off rapidly below an aspect ratio of 2. This is also the range in which the turbulence intensity becomes a function of power-jet pressure and assumes very small values at low pressures. Thus it is concluded that the most important design goal is the modification of the amplifier geometry to obtain reasonable gains at low aspect ratios and power-jet pressures while yielding a low noise coefficient. This aspect of the project will be further investigated.
(*h*) **On Mean Motion, Jet Turbulence, and Noise in Proportional Amplifiers,** T. Sarpkaya, *Proc. of the IFAC* **2,** pp. 1-7, Sec. A, June 1971.

342-08502-540-00

VORTEX BREAKDOWN ABOVE DELTA WINGS IN TRANSONIC FLOW

(*c*) T. Sarpkaya, Professor.
(*d*) Theoretical and experimental.
(*e*) Determine the effect of compressibility on vortex breakdown above delta-wings at high angles of attack in a transonic flow.
(*g*) A theoretical solution has been obtained for the transonic flow field where the phenomenon of vortex separation from the side-edges is approximated by introducing into the analytical flow field a ray of singularity possessing the vortex behavior. The strength and the location of the vortex sheet were determined by assuming (and justifying the assumptions) that the flow field around the edges is bounded and that the vortex system is dynamically free. In view of the scarcity of experimental results, it was decided to perform pressure and moment measurements as well as flow visualization experiments. The vortex cores were visualized by injection of smoke and photographing through a flash unit. The work is in progress and the results will be incorporated into a report.

342-08503-000-00

STABILITY OF HAGEN-POISEUILLE FLOW WITH SMALL SWIRL

(*c*) T. Sarpkaya, Professor.
(*d*) Theoretical.
(*e*) A theoretical investigation of this problem has been undertaken and has shown that very small amounts of swirl can render the flow unstable. In short, the theoretical context of the study is a global theory in which the linear limit gives sufficient conditions for instability, and the energy limit gives sufficient conditions for stability. Ordinarily these two limits do not coincide when one considers only small, non-spiraling disturbances.

(*g*) We show that, with small swirl, these two limits can coincide and that there is a stability limit (a relatively low Reynolds number) below which the flow becomes unstable. Thus the observed instabilities of laminar flow in pipes are consequences of initial swirl present in the flow and not a consequence of initial small disturbances.

342-08504-030-00

SUPERSONIC FLOW ABOUT AXI-SYMMETRIC BODIES AT LARGE ANGLES OF ATTACK

(*c*) T. Sarpkaya, Professor.
(*d*) Theoretical and experimental.
(*e*) The present theoretical and experimental work is aimed at filling the existing gap partly for the purpose of providing design information to aerospace industry and partly for the purpose of understanding the fluid dynamics of separated, unsteady, turbulent flows.
(*g*) The results so far obtained have revealed three rather interesting regions of flow; separation region, vortex growth region, and fully developed turbulent flow region in which there is no observable vortex shedding. The forces acting on the bodies are being measured for both the steady and unsteady motions of the body.

342-08505-550-22

AIR BREATHING PROPULSORS

(*b*) Naval Weapons Center, China Lake.
(*c*) R. H. Nunn, Assoc. Professor.
(*d*) Theoretical.
(*e*) Develop an analytical model to evaluate the effects of geometry control on external-ramp-inlet ramjet performance.
(*f*) Suspended.
(*g*) An analytical model has been mechanized to predict the effect of inlet and/or nozzle area variations upon selected ramjet performance indicators.
(*h*) **Ramjet Area Control by Fluid Injection,** R. H. Nunn, *NPS-59Nn71031B*, Mar. 1971.

342-08506-600-22

FLUID INTERACTION CONTROL TECHNIQUES

(*b*) Naval Air Systems Command.
(*c*) R. H. Nunn, Assoc. Professor.
(*d*) Theoretical, experimental, Master's thesis.
(*e*) Provide analytical backup and investigate experimentally engineering concepts in fluidic controls for tactical missiles.
(*g*) Several related areas have been studied, see (h) for detailed results.
(*h*) **Fluid Interaction Control Techniques for Air Launched Missiles,** R. H. Nunn, *NPS-59NN71121B*, Dec. 1971.
Jet Penetration and Interaction at a Sonic Throat, K. Frick, *NPS Thesis*, Mar. 1972.
Aerodynamic Throttling of Two-Dimensional Nozzle Flows, R. H. Nunn, H. Brandt, to be published in *Aeronautical Quarterly*.

342-08507-030-22

FLOW STUDIES OF AXISYMMETRIC BODIES AT EXTREME ANGLES OF ATTACK

(*b*) Naval Weapons Center, China Lake.
(*c*) R. H. Nunn, Assoc. Professor.
(*d*) Theoretical, experimental, Ph.D. thesis.
(*e*) Identify, characterize and measure the flow field in the wake of an axisymmetric body at high angles of attack from 0 to 90°.
(*g*) This project has recently been initiated. Preliminary results have been reported in monthly progress reports to the Naval Weapons Center.

342-08508-870-00

OIL SET-UP DUE TO CURRENT

(*c*) C. J. Garrison, Asst. Professor.
(*d*) Theoretical.
(*e*) Analytically describe the processes by which current and oil set-up are coupled.

342-08509-420-00

WAVE FORCES ON A SUBMERGED CYLINDER

(*c*) C. J. Garrison, Asst. Professor.
(*d*) Theoretical and experimental.
(*e*) Analytical determination and experimental variation of wave forces upon deep and shallow bodies.
(*h*) **Interaction of Waves with Submerged Objects,** C. J. Garrison, V. Seetharama Rao, *J. Waterways, Harbors and Coastal Engrg. Div., Proc. ASCE* **97,** WW2, May 1971, p. 259-277.
Interaction of a Train of Regular Waves with a Rigid Submerged Ellipsoid, V. Seetharama Rao, C. J. Garrison, *Res. Rept. TAMU-SG-71-209*, May 1971.
Forces Exerted on a Submerged Oil Storage Tank by Surface Waves, C. J. Garrison, P. Y. Chow (submitted to *J. Waterways, Harbors and Coastal Engrg. Div., ASCE*). Presented at Offshore Technology Conf., April 1972.

342-08510-030-00

ADDED MASS OF A CIRCULAR CYLINDER IN CONTACT WITH A RIGID BOUNDARY

(*c*) C. J. Garrison, Asst. Professor.
(*d*) Theoretical and experimental.
(*e*) Utilize new analytical model to describe the effect of adjacent rigid boundaries upon body added masses.
(*f*) Completed.
(*h*) **Virtual Mass of Plates and Discs in Water,** C. J. Garrison, *J. Hydraul. Div., Proc. ASCE* **97,** HY4, Apr. 1971, pp. 631-635.

342-08511-390-00

HYDRODYNAMIC LOADS INDUCED BY EARTHQUAKES

(*c*) C. J. Garrison, Asst. Professor.
(*d*) Theoretical.
(*e*) Analytically describe current transmission and arrival of hydrodynamic forces due to earthquakes.
(*h*) **Hydrodynamic Loads Induced by Earthquakes,** C. J. Garrison, presented at *Offshore Technology Conf.*, Apr. 1972.

342-08512-690-00

PULSATING SUBSONIC FLOW IN A CONICAL NOZZLE

(*c*) T. M. Houlihan, Asst. Professor.
(*d*) Experimental, theoretical, Master's thesis.
(*e*) Phase and amplitude relations between pressure and velocity are analytically predicted and experimentally measured for subsonic compressible flow.
(*f*) Suspended.
(*g*) Good agreement is found between the experimental measurements and the analytical predictions.
(*h*) **Pulsating Subsonic Flow in Convergent Nozzles,** T. M. Houlihan, Lt. E. J. Carlson, USN, presented at *NAAC Symp.*, White Oak, Md., May 1972.
An Experimental Investigation of Pulsating Subsonic Flow in a Conical Nozzle, E. J. Carlson, *NPS Master's Thesis*, Sept. 1971.

U.S. NAVAL POSTGRADUATE SCHOOL, Department of Meteorology, Monterey, Calif. 93940. Dr. George J. Haltiner, Department Chairman.

343-08513-450-00

DEVELOPMENT OF A SIMPLE, LONG-TERM, LARGE-SCALE AIR-SEA INTERACTION MODEL

(*c*) Lcdr. W. R. Lambertson, SMC1161.
(*d*) Theoretical, basic research for Doctoral degree.

(*e*) Long-term, large-scale energetics of a simple coupled ocean-atmosphere model are investigated. The model combines a 2-level quasi-geostrophic atmospheric model with a 3-level, baroclinic, Primitive Equation ocean model. Initialization techniques that allow a state of quasi-equilibrium to be reached with a minimum expenditure of computer time are examined. Calculations of transports in both the ocean and atmosphere are made. A spectral analysis will be made to determine any periods of free oscillation in the coupled system.
(*g*) The model has been run to 15,000 days where a state of quasi-equilibrium is being approached. Atmospheric disturbances and heat transports are highly dependent on the parameterization of latent heating.

343-08514-450-00

OCEAN ENERGETICS

(*b*) Foundation Research Program.
(*c*) Dr. Robert L. Haney, Code 51Hy.
(*d*) Theoretical; basic research.
(*e*) The energy cycle of the large-scale ocean circulation is being investigated using a six-level numerical ocean circulation model. The goal is to better undestand the combined efforts of wind and thermal forcing in determining the large-scale ocean circulation.
(*g*) A flux-type thermal boundary condition for ocean circulation model is presented which better simulates the large-scale thermal coupling between the atmosphere and the ocean. The more common use of a specified ocean surface temperature does not simulate this coupling properly.
(*h*) R. L. Haney, *J. Phys. Oceanog.* **1**, 4, 241-248, 1971.

343-08515-450-22

DEVELOPMENT OF A MULTI-LEVEL OCEAN PREDICTION MODEL

(*b*) Fleet Numerical Weather Central.
(*c*) Dr. Robert L. Haney, Code 51Hy.
(*d*) Theoretical; applied research.
(*e*) A multi-level dynamical numerical model of the large-scale ocean circulation is being developed for the purpose of oceanographic forecasting. The model is similar in design to general circulation models of the ocean and does not contain tidal motions or external gravity waves.
(*g*) The model is in the very early stages of development.

343-08516-460-20

TEMPERATURE FLUCTUATIONS AND SENSIBLE HEAT FLUX ABOVE WAVES

(*b*) Office of Naval Research.
(*c*) Dr. K. L. Davidson.
(*d*) Experimental analyses, basic research for M.S. theses.
(*e*) Examine features of the temperature and velocity fluctuations above natural water waves to determine if the waves had any influence on the near surface sensible heat transfer. The feature examined in most detail was the occurrences of microthermals or convective plumes. Velocity data were combined with temperature data in order to gain some understanding of the structure and formation mechanism of the microthermals. The contributions these phenomena made to the total sensible heat flux were considered along with possible influences they may have on optical propagation in the near surface layer.
(*f*) Completed.
(*g*) Two proposed mechanisms for the formation of the plumes were examined, a purely convective mechanism and one related to vortices within the mean shear. Evidence was observed in three sets of data which supported both of these proposed mechanisms. The latter was related to features of the airflow above waves. Sensible heat flux computations revealed that the microthermals represented only ten percent of the period but were responsible for approximately 35 percent of the sensible heat flux.
(*h*) **Temperature Fluctuations and Sensible Heat Flux Above Waves,** K. L. Davidson, G. W. Safley, *Proc. XV Conf. Great Lakes Res.*, Madison, Wisc., Apr. 1972.
Investigations on the Temperature Fluctuations and Incidence of Microthermals in the Air Adjacent to Natural Water Waves, G. W. Safley, *Master's Thesis*, Dept. of Meteorology, NPS, March 1972.

343-08517-460-20

AN INVESTIGATION ON ORGANIZED MOTION OVER WAVES

(*b*) NPS Foundation Research Program and Office of Naval Research.
(*c*) Dr. K. L. Davidson.
(*d*) Experimental analyses, basic research.
(*e*) Develop and evaluate procedures for examining the influence of natural water waves on the adjacent turbulent airflow. The procedures are based on joint probability-conditional means analyses. The procedures were applied to data which had been previously examined with spectral analyses. The results obtained from the newly formulated procedures were compared with previous results and with theoretical predictions for wind-wave coupling.
(*f*) Completed.
(*g*) The statistical procedures proved to be very good in that nonlinear features associated with the interaction between the wave-induced motion and turbulence in the shear flow were identified. These features were not delineated by previous spectral analyses since the latter analysis is based on linear expansions of the fluctuations. The most striking results appear to be those representing the average phase-amplitude relations. Interpretations on these results were limited by the small amount of data and conditions available for the study.
(*h*) **Properties of Wave-Related Fluctuations in the Airflow Above Natural Waves,** K. L. Davidson, A. J. Frank, *J. Phys. Oceanog.*, Jan. 1972. Typescript available. Will be issued as an NPS report in 1972.
An Investigation on the Properties and Influence of Wave-Induced Motion in the Adjacent Airflow, A. J. Frank, *Masters Thesis*, Dept. of Meteorology, NPS, Sept. 1971.

343-08518-460-20

AN INVESTIGATION ON TURBULENCE DATA OBTAINED OVER OCEAN WAVES

(*b*) Office of Naval Research.
(*c*) Dr. K. L. Davidson.
(*e*) Complete analyses and interpretations on velocity, temperature and wave data obtained during the BOMEX experiment of 1969. The data will be processed to obtain estimates of momentum and sensible heat flux adjacent to ocean waves and to obtain information on the influence of the waves on these processes. Analyses procedures include spectral and joint probability-conditional means methods.
(*g*) Computations have been made of variances of individual variables and covariances between pairs of variables. Normalized intensities, $\sigma v_c/u_x$, appear to be dependent on c/u, where σv_i is standard deviation of velocity components, u_x is friction velocity and c is phase speed corresponding to peak of the wave spectra. Spectral estimates have revealed significant energy in velocity fluctuations at frequencies corresponding to the predominant surface wave. Cospectral estimates have revealed extrema at the frequency of the predominant surface wave which is indicative of significant wind-wave coupling as predicted by theoretical formulations.
(*h*) **The Influence of Water Waves on the Adjacent Air Flow,** K. L. Davidson, D. J. Portman, *Symp. on Air-Sea Interaction, XV General Assembly of IUGG*, Aug. 1971, Moscow, USSR. Typescript available.
Application of Parametric Methods to Descriptions of Wave-Induced Fluctuations in the Adjacent Airflow, Ens. Craig Smith, *Master Thesis*, Dept. of Meteorology, NPS, July 1972.

Wave-Related Disturbances in the Velocity Field Over Ocean Waves, Lcdr. Stanley Thompson, *Master Thesis*, Dept. of Meteorology, NPS, Sept. 1972.
An Investigation on Sensible Heat Transfer Over Ocean Waves, Lt. David Ihle, *Master Thesis*, Dept. of Meteorology, NPS, Sept. 1972.
An Examination on the Generation and Properties of Microthermals with Near-Neutral Stratifications Over Ocean Waves, Lt. Glenn Bingham, *Master Thesis*, Dept. of Meteorology, NPS, Sept. 1972.

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U.S. NAVAL POSTGRADUATE SCHOOL, Department of Oceanography, Monterey, Calif. 93940. Dr. D. F. Leipper, Department Chairman.

344-06595-010-22

BOUNDARY LAYER TURBULENCE

(*b*) Naval Ordnance Systems Command, Washington, D.C.
(*c*) Dr. Warren W. Denner and Noel E. J. Boston, Assoc. Professors.
(*d*) Theoretical and experimental research.
(*e*) The turbulent microstructure of the wind and temperature fields immediately above wind generated waves is being investigated. The purpose is to determine the significance of this layer by transporting heat and momentum.
(*g*) Turbulent wind and temperature data are being examined to determine significance of bursts of energy on vertical transports.
(*h*) **Analysis of Temperature and Velocity Fluctuations in the Atmospheric Boundary Layer,** T. E. Gill, *MS Thesis*, NPS, Mar. 1971.
A Statistical Model of Atmospheric Temperature Signals, E. M. Kline, *MS Thesis*, NPS, Mar. 1972.
Time Series Analysis at the Naval Postgraduate School, R. D. Jones, *MS Thesis*, NPS, Mar. 1971.

344-07059-450-22

ARCTIC MICROSTRUCTURE AND ACOUSTIC PROPAGATION

(*b*) Naval Ordnance Systems Command, Washington, D.C.
(*c*) Dr. Warren W. Denner, Assoc. Professor.
(*d*) Theoretical and field investigations of the microstructure in the Arctic and the interaction of acoustic waves with this microstructure.
(*e*) Measurements of the thermal microstructure and acoustic wave interaction are being made and analyzed.
(*g*) Measurements are being made of acoustic pressure amplitude fluctuations as related to changes in the ocean environment. The questions raised by recent work are being examined when both a turbulent microstructure and internal waves are present in a stratified medium.
(*h*) **Temperature and Conductivity of Measurements under Ice Island T-3,** W. W. Denner, V. Neal, S. Neshyba, *J. Geophys. Res.* **76**, 33, Nov. 1971.
Layered Temperature Microstructure and Internal Waves in the Arctic, W. W. Denner, V. Neal, S. Neshyba, *J. Phys. Oceanog.* **2**, 1.
An Examination of Microthermal Structure Statistics as Calculated from Expendable Bathythermograph Records, F. M. Hunt, *MS Thesis*, NPS, Sept. 1971.

344-08519-450-20

SMALL SCALE INTERACTIONS IN THE UPPER OCEAN

(*b*) Office of Naval Research.
(*c*) Dr. Noel Boston, Assoc. Professor, Dr. E. B. Thornton, Asst. Professor, Dr. H. Medwin, Professor.
(*d*) Theoretical and experimental research.
(*e*) Measurements of ocean surface height, water particle velocities, temperature and salinity fluctuations, acoustic amplitude fluctuations and acoustic phase modulation have been made and are continuing to be made from the Naval Undersea Research and Development Oceanographic Tower off Mission Beach, California.
(*g*) Spectra and correlations of these parameters have been computed. Strong correlations have been found between particle velocities and wave heights and between the sound parameters and wave heights.
(*h*) **Amplitude Modulation of an Acoustic Wave Propagating Near the Sea Surface,** W. J. Smith, *Tech. Rep. NPS-61Md72021A*, Feb. 1972.
The Measurement and Correlation of Sound Velocity and Temperature Fluctuations Near the Sea Surface, C. J. Duchock, *MS Thesis*, NPS, Mar. 1972.
Sound Dispersion and Phase Fluctuations in the Upper Ocean, J. Rautmann, *MS Thesis*, NPS, Dec. 1971.
Statistical Relations Between Salinity, Temperature and Speed of Sound in the Upper Ocean, H. A. Seymour, *MS Thesis*, NPS, Mar. 1972.
Spectral Measurement of Water Particle Velocities Under Waves, M. W. Bordy, *MS Thesis*, NPS, Mar. 1972.

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U.S. NAVAL POSTGRADUATE SCHOOL, Department of Physics, Monterey, Calif. 93940. J. V. Sanders, Associate Professor.

345-07060-250-00

DRAG COEFFICIENTS OF SPHERES IN DILUTE AQUEOUS SOLUTIONS OF HIGH POLYMERS

(*d*) Experimental; Master's thesis.
(*e*) The trajectories of spheres freely falling in water were determined from stereoscopic photographs and the measured terminal speeds used to determine the drag coefficients and Reynolds numbers. The size and density of the spheres were chosen to cover a Reynolds number range from 10×10^5 to 7×10^5. Measurements in dilute aqueous solutions of drag-reducing polymers are presently being conducted.
(*g*) Spheres attaining Reynolds numbers less than the critical value (2.2×10^5) display little scatter in the terminal speeds. The same is true for spheres attaining the highest Reynolds numbers studied. Spheres with Reynolds numbers immediately above the critical value frequently deviate from a straight trajectory and, even when falling fairly straight, show a scatter in terminal speeds as great as 20 percent. The drag coefficient vs. Reynolds number curve agrees with that obtained in wind tunnels with the critical Reynolds number unchanged and the drag coefficients for freely-falling spheres being no more than 20 percent higher than the wind-tunnel results.
(*h*) **Drag of Free-Falling Spheres in Water for Reynolds Numbers Near Critical,** G. F. Nolan, *M.S. Thesis*, NPS, Sept. 1970. (DDC Cameron Station, Alexandria, Va. 22314).

345-08520-250-00

EFFECT OF MOLECULAR SIZE ON THE FRICTION REDUCTION IN PIPES

(*d*) Experimental; Ph.D. thesis.
(*e*) The pressure gradients and volume flow rates for the flow of dilute aqueous solutions of polyethylene oxide were measured in smooth pipes with nominal diameters of 1/4, 3/8, and 3/4 in. Pressurization of the reservoir allowed complete coverage of the Reynolds number range from 2×10^3 to 2×10^5, thereby including laminar, transition, and turbulent regimes. The intrinsic viscosities of samples withdrawn from the flow were determined with a dilution capillary viscometer and the Mark-Houwink relation was used to calculate the molecular weight of the polymer. Polymer concentrations ranged from 0 to 50 wppm.
(*f*) Completed.
(*g*) For a given polyethylene-oxide grade, when the wall shear stress exceeded the 'critical' value, the amount of drag reduction depended only on the concentration and the

Reynolds number and was independent of the pipe diameter. In contrast, below the 'critical' wall shear stress, the friction coefficient and the very shape of the curve in the transition regime depended on the pipe diameter. The measurement of molecular size showed that the polymer was physically degrading under flow conditions and spectroscopic measurements indicated that this was due to mechanical (not chemical) processes. The relative volume of solution occupied by the polymer molecules (as represented by the volume of the 'equivalent' hydrodynamic spheres) was found to be the dominant parameter governing the amount of drag reduction. It was demonstrated that if solutions of polyethylene oxide have their molecules occupying the same relative volume then, irregardless of the concentrations, they will have the same drag reduction at all Reynolds numbers. This was shown to be true for solutions made from different grades (WSR-301, -205, -35, N-3000), for mixtures of grades, and for degraded solutions.

(*h*) **A Correlation Between Friction Reduction and Molecular Size for the Flow of Dilute Aqueous Polyethylene-Oxide Solutions in Pipes,** J. W. Kinnier, *Ph.D. Thesis*, NPS, June 1970, (DDC Cameron Station, Alexandria, Va. 22314).

345-08521-250-00

EFFECT OF DRAG-REDUCING FLUIDS ON THE PRESSURE SIGNATURES OF SUBMERGED BODIES

(*d*) Experimental; Master's thesis.

(*e*) The pressure signatures of a cylindrical body, 9-in. long and 1 in. in diameter, moving at constant speeds of 1.57, 1.84, and 2.36 m/s in aqueous solutions of polyethylene oxide WSR-301 at concentrations of 0, 50, 100, and 200 wppm were investigated under laminar flow conditions; Reynolds numbers, based on length, were in the range from 3.6×10^5 to 5.4×10^5. A regular laminar flow pattern was investigated with a body with a hemispherical bow and tapered stern, and a laminar flow pattern with forced fluid separation followed by reattachment was investigated with a body with a squared-off bow and a tapered stern. A barium titantite hydrophone was used as the sensor.

(*f*) Completed.

(*g*) A small whirling-arm apparatus was developed for investigating the pressure signatures of submerged bodies of length less than one foot. No apparent difference in the pressure signatures was found which could be attributed to the addition of the polymer into solution.

(*h*) **Pressure Signatures of a Cylindrical Body Moving in Aqueous Solutions of Polyethylene Oxide,** R. C. Witter, *M.S. Thesis*, NPS, Dec. 1970 (DDC, Cameron Station, Alexandria, Va. 22314).

345-08522-250-00

EFFECTS OF DRAG-REDUCING ADDITIVES ON THE HYDRODYNAMIC AND ACOUSTIC PERFORMANCE OF A SMALL PROPELLER

(*d*) Experimental; Master's thesis.

(*e*) Thrust and torque were measured and efficiency calculated for a 14.6-cm diameter, two-bladed propeller in aqueous solutions of polyethylene oxide WSR-301. These measurements were performed in an annular channel with the propeller under test providing the motive power and the load on the propeller controlled by a flow restricter. Acoustic measurements were made on the discrete bladeline signal and on the cavitation noise. The range of parameters studied was; polymer concentration from 0 to 75 wppm; advance coefficient 0.04 to 0.2; and rotation speed from 850 to 2000 rpm.

(*f*) Complete.

(*g*) For the propeller operating under heavily loaded conditions, the thrust decreased with increasing concentration while the torque passed through a minimum at 10 wppm. The net result was that the propeller efficiency remained essentially constant except for a small increase of a few percent at 10 wppm. The polymer greatly reduced the rate of propeller cavitation but did not influence the rotational speed at which cavitation was first noticed. The polymer had no effect on the SPL of the fundamental blade line.

(*h*) **Effects of Polyethylene-Oxide Solutions on the Performance of a Small Propeller,** L. H. Henderson, *M.S. Thesis*, NPS, Sept. 1971 (DDC, Cameron Station, Alexandria, Va. 22314).
Propeller Cavitation in Solutions of Polyethylene Oxide, R. J. White, *M.S. Thesis*, NPS, Dec. 1971 (DDC, Cameron Station, Alexandria, Va. 22314).

U.S. NAVAL RESEARCH LABORATORY, Washington, D.C. 20390. Earle W. Sapp, CAPT, USN, Director.

346-07063-020-00

DIFFUSIVITY OF HEAT AND SALINITY IN WATER

(*c*) Dr. Allen H. Schooley, Code 8303, Building 208.

(*d*) Experimental exploratory applied research.

(*e*) Molecular and eddy diffusivity in water is measured with no turbulence and controlled amounts of increasing turbulence.

(*g*) The ratio of molecular thermal diffusivity to molecular diffusivity of salt (sodium chloride solution) in water is about 130. As turbulence is increased the ratio of the eddy diffusivities decrease, and may approach unity.

346-07064-460-00

VISCOUS FLOW IN THE AIR AND WATER WITHIN THE MEAN LAMINAR SUBLAYERS AT THE NAVIFACE (SEA-AIR INTERFACE)

(*c*) Dr. Allen H. Schooley, Code 8303, Building 208.

(*d*) Phenomenological applied research.

(*e*) Heat balance equations have been applied to sea measurements to determine the average thickness, temperature difference, and stress across the thin viscous sublayers in the air and in the water at the naviface.

(*g*) Heat balance at the sea surface is assumed to be dominated by the equation, $\pm Q_n \pm Q_a \pm Q_w \pm Q_e = O$ cal/cm^2/min, where Q_n is the net all-wave radiation balance. Q_a is the molecular conduction of sensible heat through the average thickness of an assumed nonturbulent air layer in contact with the sea surface. Q_w is the molecular conduction of sensible heat through the average thickness of an assumed nonturbulent laminar sublayer in the water very near the surface. Q_e is the contribution of the latent heat of evaporation. Balancing this equation under conditions of sunshine and cloud cover at sea, has given new comparisons regarding the relative thickness of the average laminar sublayers, their temperature differences, and wind stresses.

346-07065-420-00

MICROWAVE SCATTERING FROM WIND WAVES

(*c*) Dr. John W. Wright, Code 5272.

(*d*) Experimental investigation of doppler spectra in microwave scattering from wind waves in a short fetch laboratory wind/wave tank together with measurements of water wave slope spectra by photographic techniques.

(*g*) At high angles the dominant wind wave is the dominant scatterer; at lower angles the scatterers comprise wave systems which are respectively bound to and free of the dominant wave. The bound waves are analogous to parasitic capillary waves at low winds. The free waves are roughly short gravity and capillary waves but differ from the classical irrotational wave in that they possess a markedly windspeed dependent phase speed. The reason appears to be that these free waves evolve from the wind drift, the highly sheared wind induced flow at the air water interface.

(*h*) **Slope Spectrum of Capillary Waves in a Wave Tank,** W. C. Keller, *NRL Rept. of Progress*, pp. 18-19, Feb. 1969.

346-07066-030-00

WAKE EXPANSION IN SIMULATED ENVIRONMENTS

(*c*) Kingley C. Williams, Code 8340.
(*d*) Experimental, exploratory research.
(*e*) Models are used to study wake expansion phenomena in complex environments, including density gradients and overturn. Related theory is being developed.

346-07067-420-00

SEA SPECTRA ANALYSIS

(*c*) Denzil Stilwell, Jr., Code 5273.
(*d*) Field investigation of a novel technique of sea spectra measurement and basic research into the behavior of the sea surface.
(*e*) This project involves the processing of photographs of the sea surface taken under specified conditions to obtain the two-dimensional energy density spectrum of the height variations on the sea surface. This is accomplished by analyzing the diffraction pattern of the density variations on the sea photograph and relating it to the energy density spectrum. In addition, studies of the ocean wave spectra are being made from an EC-121 platform to determine the magnitude and variability of the sea surface.
(*g*) The Sea Photo Analysis (SPA) technique has been verified by simultaneous measurement of the sea surface variation by SPA and by wave staffs. The technique has also been verified in laboratory wave tanks. Work is continuing to use SPA on aerial photos taken from the EC-121 platform.
(*h*) **Directional Energy Spectra of the Sea from Photographs,** D. Stilwell, Jr., *J. Geophys. Res.* **74**, 8, pp. 1974-1986, Apr. 1969.

346-08523-250-20

DRAG REDUCTION

(*b*) Office of Naval Research and Naval Ship Systems Command.
(*c*) R. C. Little, Code 6170.
(*d*) Experimental and theoretical applied research.
(*e*) Combined experimental and theoretical investigations are being made of the drag reducing ability of polymers and association colloids in both aqueous and nonaqueous environments. An improved understanding of the mechanism of drag reduction will allow the synthesis of even more effective agents for both Naval and civilian applications. The ultimate objective of the project is to relate the observed drag reduction effect to the molecular and micellar structure of the agents used.
(*f*) The onset point of early turbulence effects under laminar flow conditions has been shown to be virtually equal to the onset point of drag reduction in fully developed turbulent flow. Explanations for this behavior were advanced on both molecular and hydrodynamic instability bases. Highly efficient aqueous asbestos dispersions were also prepared which appear to be fully as efficient as several popular drag reducing agents on a weight percent basis. Numerical indices of drag reduction efficiency and shear stability have been developed to aid the characterization of agents as their molecular and micellar structures are systematically varied. Recent theoretical work based on a modified polymer dumbbell model suggests that viscoelastic effects on the mean local rate of energy dissipation of a fluid element in an oscillatory motion may be quite small but that large increases in elongational viscosity may be experienced as the stretching rate exceeds a critical value and the terminal relaxation time of the fluid is exceeded.

346-08524-250-00

THEORETICAL INVESTIGATIONS OF DRAG REDUCTION AND EARLY TURBULENCE

(*c*) Robert J. Hansen, Code 8441.
(*d*) Theoretical, applied research.
(*e*) The drag reduction phenomenon has been studied by combining a mathematical model for the turbulent boundary layer with constitutive equations which provide a qualitatively correct rheological description of polymer solutions. As a first step in explaining early turbulence, the same constitutive equations have been employed in studying the stability of high-phase-velocity disturbances in laminar pipe flows.
(*g*) A relationship has been established between the reduced drag of polymer solutions in turbulent flows and a heretofore unrecognized drag reduction effect in transient-laminar flows. Qualitatively correct predictions of the flow rate-wall shear stress behavior observed with polymer solutions in pipe flows were obtained. The polymer additive is predicted to have a destabilizing effect on the flow above a critical onset condition and a stabilizing effect otherwise. This result is consistent with the view that early turbulence is a hydrodynamic instability phenomenon.
(*h*) **The Relationship of Drag Reduction to the Transient Laminar Shear Flow Properties of Polymer Solutions,** R. J. Hansen, *NRL Report 7274*, June 1971.
Measurements to Elucidate the Mechanism of Drag Reduction, R. J. Hansen, *Symp. on Turbulence in Liquids*, Univ. of Missouri-Rolla, Oct. 1971.

U.S. NAVAL SHIP ENGINEERING CENTER, PHILADELPHIA DIVISION, Applied Physics Department, Philadelphia, Pa. 19112. J. W. Murdock, Department Head. (Reports available from DDC, Cameron Station, Alexandria, Va. 22314.)

347-03623-700-00

HIGH PRESSURE-TEMPERATURE WATER FLOW METER CALIBRATION

(*d*) Experimental; applied research.
(*e*) A facility is available for calibration with water at pressures and temperatures up to 2500 psi and 600°F, respectively. Capacity is 100 gpm at maximum pressure and temperature and greater at lower pressures and temperatures. After flowing through the metering section the water is cooled and weighed. The facility is also used to investigate and verify orifice meter coefficients at pressures and temperatures above those at which the coefficients in use were established. A number of flow meters which measure the flow in nuclear reactor loops have been calibrated.
(*f*) Inactive.
(*g*) A limited amount of test data indicate good agreement between orifice flow rates obtained by calibration at high pressures and temperatures and those obtained by extrapolating from cold water calibrations. Other meter tests show the need to include suitable corrections for change in shape, size, density, etc.

347-07068-700-00

TOWARD A CONSTANT COEFFICIENT OF DISCHARGE FROM A NOZZLE VIA NEW PRESSURE TAP LOCATIONS

(*d*) Experimental; applied research.
(*e*) Flow nozzle discharge coefficients are a function of boundary-layer displacement thickness. For a given nozzle shape, the throat Reynolds number is directly related to boundary-layer Reynolds number so that correlation of nozzle coefficients can be obtained in terms of R_d. The present state-of-the-art of the flow nozzle gives discharge coefficients within one percent of unity above a Reynolds number of 1.3×10^6. The objective of this project was to increase the range of Reynolds number over which the flow nozzle coefficient of discharge is within one percent of unity. It was necessary to modify basic nozzle design using techniques of boundary-layer control and determine optimal positioning of pressure taps to maximize the discharge coefficient. ASME nozzles were subjected to the coefficient optimizing design modifications.

(*f*) Completed.
(*g*) Two improvements were made to a long radius flow nozzle which could make these differential pressure head class elements more useful to the Navy. These were modifications to the locations of the downstream pressure taps resulting in improved discharge coefficients. The pipe Reynolds number ranged between 20,000 and 500,000 while testing the 0.4 Beta ratio nozzle. The first modifications resulted in a nearly constant coefficient of about 0.985 over the whole range of Reynolds number. The second resulted in a constant coefficient of about 0.996 for pipe Reynolds numbers below 62,500 down to 20,000. The nearly constant discharge coefficient greatly facilitates the application of these elements to Naval shipboard piping, for example, as sensors for fuel oil metering in automatic combustion control systems.
(*h*) **Toward a Constant Coefficient of Discharge for a Nozzle via New Pressure Tap Locations,** D. R. Keyser, *NAVSEC-PHILADIV Rept. A-900*, Mar. 1971.

347-07071-700-00

AN EXPERIMENTAL AND THEORETICAL INVESTIGATION OF CONIC ENTRANCE ORIFICE PERFORMANCE IN THE LOW REYNOLDS NUMBER DOMAIN

(*d*) Experimental; applied research.
(*e*) Head-type primary elements are, as a class, weak in low Reynolds number ranges. Their coefficients exhibit a large deviation from linearity in this area making their use for many purposes suboptimal at best. A primary element with a relatively flat discharge coefficient could be of significant value in certain shipboard applications. The conical entrance orifice was developed by George Kent Ltd., England. It is asserted to have a flat coefficient of discharge varying from 0.72 to 0.76 over a Reynolds number range of 200 to 50,000. The International Standards Organization Committee ISO/TC 30 has issued a preliminary draft specification for this orifice. In cooperation with both ISO/TC 30 and ASME, analysis of the performance of the conical entrance orifice is being conducted.
(*f*) Completed.
(*g*) Twelve conic entrance plates were tested to ascertain their performance characteristics for flow measurement at unusually low Reynolds numbers. The range of values for orifice to pipe diameter ratios, β, was 0.1 to 0.5, and pipe Reynolds numbers ranged from 40 to 50,000. Performance worsened with increasing β, and the discharge coefficient may not be considered constant within ± 1 percent maximum variation over the specified range of Reynolds number for β greater than 0.1. For $\beta \geqslant 0.2$ the discharge coefficient may be considered constant within ± 2 percent maximum variation. Characteristic of the graphs of discharge coefficient versus Reynolds number was a "hump" which consistently occurred in the region just below the critical Reynolds number for pipe flow (about 2000). Theoretical considerations showed that this hump is attributable to fluid viscosity and that its height might be lessened by geometrical modifications. Accordingly, qualitative arguments are presented which contend that a protruding conic edge might improve performance at low Reynolds numbers. As it stands, the conic entrance orifice is to be preferred to the common, square edged orifice where low Reynolds numbers are encountered. The device is not unique, however, since quadrant edge orifices are also well-suited for such measurements.
(*h*) **An Experimental and Theoretical Investigation of Conic Entrance Orifice Performance in the Low Reynolds Number Domain,** R. F. Bruner, *NAVSECPHILADIV Rept. A-1000*, Mar. 1972.

347-07072-700-00

DETERMINATION OF ELBOW METER FLOW COEFFICIENTS

(*d*) Experimental; applied research.
(*e*) Obtain knowledge of the effects of pipe size and Reynolds number on the flow coefficient of elbow meters in the nominal pipe sizes below 1-1/4 inch and below Reynolds number of 70,000.
(*f*) Completed.
(*g*) Elbow meter flow coefficients were obtained for nominal pipe sizes from 1/2 inch to 1-1/4 inch and at Reynolds numbers significantly below 70,000. This data correlated well with previously published elbow meter coefficient vs. Reynolds number relationships. The new data will supplement this currently published information and become a part of a U.S. Navy Mechanical Standard Drawing on elbow meters.
(*h*) The new data has not been published in a formal report or technical paper for a professional society. Information on these findings can be obtained by contacting Mr. J. W. Murdock, Head, Applied Physics Department.

347-08525-700-00

EVALUATION AND ANALYSIS OF UNIVERSAL VENTURI PRIMARY FLOW METERING DEVICE

(*d*) Experimental; applied research.
(*e*) Most head-type flow measurement devices are inappropriate for shipboard use due to limitations inherent in the ship's pipe systems. The chief limitation is the effect of upstream piping configuration on the flow coefficient. Development of a flow metering device which is relatively insensitive to upstream piping would be a significant improvement over devices now in use, as well as provide for possible future use in more sophisticated ship systems. In this connection the Universal Venturi is being investigated to determine its efficacy in the relatively complex pipe configurations typical of ship systems.
(*g*) Preliminary planning has been completed and a test agenda formulated. Experimentation will commence upon receipt of meter sections now being procured. Experiments will cover several β ratios and sizes.

U.S. NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, CARDEROCK LABORATORY, Bethesda, Md. 20034. W. E. Cummins, Head, Ship Performance Department.

348-08526-230-00

HYDRODYNAMIC CAVITATION STUDIES

(*c*) Dr. F. B. Peterson, Hydrodynamics Branch.
(*d*) Experimental work primarily; basic research.
(*e*) Determination of physical properties of water and bodies which are responsible for cavitation inception and associated noise. Development of holographic technique for measurement of free gas content and acoustic methods and high speed photography for determination of cavitation and its detailed nature.
(*g*) Holographic technique development completed.

348-08527-010-00

BOUNDARY LAYER STUDIES

(*c*) J. Power or C. von Kerczek, Hydrodynamics Branch.
(*d*) Experimental work; applied research.
(*e*) Wind tunnel study of three-dimensional turbulent boundary layer velocity field and shear stress distribution when cross-flows occur.
(*g*) Preliminary experiments have been completed.

348-08528-010-00

CALCULATION OF SHIP BOUNDARY LAYERS

(*c*) C. von Kerczek, Hydrodynamics Branch.
(*d*) Theoretical work; applied research.
(*e*) Development of methods for prediction of ship boundary layers and skin friction by integral method. Initial study makes assumption of small crossflow and zero Froude number. Later work to relax these constraints.
(*g*) Study to be completed in 1974.

348-08529-040-22

TWO-DIMENSIONAL ADDED-MASS AND DAMPING FOR BODIES OSCILLATING IN A FLUID OF FINITE DEPTH

(*b*) Naval Ship Systems Command.
(*c*) Mr. D. J. Sheridan, Ship Performance Department.
(*d*) Theoretical; applied research.
(*e*) A method for predicting the two-dimensional added-mass and wave damping for arbitrary bodies was developed for shallow water flows using a closefit source distribution technique.
(*g*) The potential function for a single source oscillating in a fluid of finite depth has been developed.

348-08530-550-00

SKEWED PROPELLER DEVELOPMENT

(*c*) Dr. W. B. Morgan, Head, Hydromechanics Division.
(*d*) Experimental; development.
(*e*) The effect of blade warp (a combination of skewback and forward rake which places the centerline of all blade sections in the same plane normal to the shaft axis) is to be investigated in detail. Two warped propellers have been designed. These propellers differ from existing skewed propellers (skew = 36° and 72°) only in that blade warp rather than skew is being used. Model propellers have been built and tested for open-water characteristics and will be tested for cavitation inception and patterns. These results will be correlated with the results of existing corresponding skewed propellers. The propeller-induced pressures on a flat-plate over the propeller for the warped propellers will be measured using existing instrumentation, wake screens, and procedures. Pressure forces of various warped propellers and skewed propellers in the extended series will be correlated. Special emphasis will be given to accurately measure the phase angles.
(*g*) Open-water tests results showed that arbitrary raking without pitch corrections did not prove satisfactory. Preliminary results of cavitation tests of warped propellers showed a widening of the cavitation-free bracket for increasing warp. This result is similar to that found for increasing skew.
(*h*) **Design, Cavitation Performance, and Open-Water Performance of a Series of Research Skewed Propellers,** R. J. Boswell, *NSRDC Rept. 3339*, Mar. 1971.

348-08531-550-22

CONTRAROTATING PROPELLERS

(*b*) Naval Ship Systems Command, Code 034, Dept. of the Navy.
(*c*) E. B. Caster, Mathematician, Propulsor Technology Branch.
(*d*) Theoretical; development.
(*e*) To apply recent advances in propeller design-theory and numerical computation procedures to the design of contrarotating propellers and thus permit improvements in the propeller operational characteristics including cavitation performance and vibration characteristics. Open water and cavitation tests will be conducted on one set of contrarotating propellers to verify the design procedure.
(*g*) A report of work in (e) to be issued in June 1973, will include a FORTRAN listing of the contrarotating propeller design computer program adaptable to the CDC 6700 high speed computer, and test results on one set of propellers designed using the new procedures.

348-08532-550-22

DESIGN AND PERFORMANCE PREDICTION OF CONTRAROTATING PROPULSION ARRANGEMENT

(*b*) Naval Ship Systems Command.
(*c*) Jorgen Strom-Tejsen, J. L. Beveridge.
(*d*) Theoretical; applied research.
(*e*) Develop a capability for accurate prediction and design of ships with contrarotating propulsion arrangement. The hull propeller interaction phenomena associated with contrarotating propulsion arrangements will be investigated through programs combining model experiments and analytical study. Experimental program will be used to explore propulsor and control surface interaction, and interaction between hull, propulsor, and control surfaces. Factors to be investigated include loading between propellers, spacing of propellers, location and type of control surfaces, etc. Analytical study will be carried out on specific submarine and/or surface ships. Components of propulsive coefficients will be calculated by means of available propeller computer program and application of the Lagally steady-motion theorem. Theoretical results will be compared with experimental results.
(*g*) Experiments for a surface-ship model have been completed.

348-08533-550-22

BLADE TURNING EFFORT OF CONTROLLABLE PITCH PROPELLERS

(*b*) Naval Ship Systems Command.
(*c*) Stephen B. Denny.
(*d*) Experimental; development.
(*e*) Provide data applicable to the prediction of blade turning effort and blade spindle strength requirements of CP propellers. Such propellers offer advantages over fixed-pitch propellers of backing without shaft reversal and potential cavitation and noise reductions by virtue of their capability to develop a given speed through various combinations of pitch settings and rpm. No reliable data are available for predicting blade turning effort and blade spindle requirements. Instrumentation was developed and spindle torque was measured on a wide-bladed model CP propeller over a wide range of operating conditions (advance coefficients and pitch settings). Tests were conducted in the 24-inch water tunnel simulating both forward and backing conditions. Further experiments will be carried out to determine the effects of blade geometry variation such as blade area and skew.
(*g*) Testing has been completed and blade spindle torque has been determined for a 5-bladed model propeller at a range of positive and negative pitch settings and for a variety of steady and transient operating conditions. Test results are presently being analyzed and indications are that pure spindle torque data were obtained and that the dynamomctry successfully eliminated blade thrust and torque force interactions.
(*h*) **Blade Spindle Moment on a Five-Bladed Controllable-Pitch Propeller,** *NAVSHIPRANDCEN Rept. 3729*, Jan. 1972.

348-08534-550-00

SUPERCAVITATING PROPELLER DESIGN METHOD

(*c*) Dr. B. Yim.
(*d*) Theoretical work; applied research.
(*e*) Lifting line theory will be combined with cavity cascade theory to predict overall propeller performance. The detailed propeller geometry will be obtained from solution of lifting-surface theory which includes three-dimensional cavity thickness interaction effects.
(*g*) Study to be completed in 1974.

348-08535-550-22

DUCTED THRUSTER DESIGN FOR SHIP CONTROL

(*b*) Naval Ship Systems Command.
(*c*) J. L. Beveridge.
(*d*) Theoretical; applied research.
(*e*) Develop criteria for the design of ducted thrusters for naval ship and submersible control. The control of ships and submersibles by the use of transverse thrusters is necessary where precise control is required at low speeds, such as for the Deep Submergence Rescue Vehicle and other small submersibles. One of the most effective types of thruster is the impeller in a tunnel. Over the past years, NAVSHIPRANDCEN has developed a basic understand-

ing of thruster action and coupled with the general expertise of NAVSHIPRANDCEN in propulsor design, information is at hand to develop design criteria for ducted thrusters and to assemble in a form for easy use by the naval architect.
(*f*) Completed.
(*g*) An evaluation of existing analytical and experimental data was used to provide performance information and design criteria for circular transverse thrusters. Broad problem areas such as general duct arrangement, duct shape, and impeller design were considered.
(*h*) **Design and Performance of Bow Thrusters,** J. L. Beveridge, *NAVSHIPRANDCEN Rept. 3611*, Sept. 1971.

348-08536-550-22

PREDICTION OF PROPELLER INDUCED SHIP VIBRATION

(*b*) Naval Ship Systems Command.
(*c*) Stephen B. Denny.
(*d*) Theoretical; applied research.
(*e*) Develop an easily usable procedure for estimating bearing forces and moments as a function of estimated wake variation and propeller geometry. Extend procedures and instrumentation capabilities to enable measurement of total resultant unsteady forces on sterns of surface ship models. Develop analytical methods for predicting the effects of wake variation and shaft inclination on generated field pressure magnitudes. It is proposed that a procedure be developed for preliminary design use for the simplified investigation of wake and propeller geometry effects on bearing forces and moments. It will incorporate estimated wake from existing model data and propeller geometry variations. Develop instrumentation design to allow measurement of all six components of moments and forces on the stern section of a surface ship model. These tests should furnish information about the total resultant forces (rather than localized forces) on an appendaged hull propeller arrangement. An attempt will be made to extend a free space pressure calculation procedure to generate pressure predictions for comparison with existing experimental data. Should the comparisons be reasonable, a procedure would be available for predicting longitudinal wake and inclined shaft effects on field pressures. The result of this investigation would establish guidelines for determining proper propeller-hull clearances, shaft inclinations, and strut interference effects –interrelations which are quite important in design analysis of future highpower propulsion systems.
(*g*) Completion of an approximate procedure for estimating wake geometries for single and twin screw ships.

348-08537-550-22

EFFECT OF SHIP MOTION ON PROPULSIVE PERFORMANCE

(*b*) Naval Ship Systems Command.
(*c*) Jorgen Strom-Tejsen.
(*d*) Experimental; applied research.
(*e*) Develop procedure for predicting the effect of ship motion on propeller performance and propulsive factors. Propeller performance (steady and vibratory forces) and propulsive factors, (wake, thrust deduction, etc.) are, at present,determined on the basis of steady experiments in calm water. It is not likely, however, that propulsive performance in calm water applies to the dynamic situation with the ship in motion. The effect on propulsive performance due to motion such as sway and yaw, rolling, heave and pitch will be determined using captive model tests. The NAVSHIPRANDCEN Planar Motion Mechanism will be used to perform captive model tests on model of DE 1006 (Model 4360). Phase I work concentrated on sway and yaw motion and helped to establish the merits of the proposed methodology. The self-propelled model was oscillated at various frequencies and amplitudes. The effect on propulsive factors (wake, thrust deduction, etc.) and propeller performance was measured. Phase II work will involve similar tests oscillating the model in heave and pitch. Results from model experiments will be used to formulate a mathematical model (and associated computer programs) for the prediction of speed and powering characteristics for the ship moving in a seaway.
(*g*) Model test oscillating the self propelled model and open water boat has been completed. Experimental results are in the process of being analyzed.

348-08538-520-22

APPLICATION OF ANALYTICAL SHIP-WAVE RELATIONS TO SHIP-RESISTANCE STUDIES

(*b*) Naval Ship Systems Command.
(*c*) C. J. Wilson.
(*d*) Experimental; applied research.
(*e*) This project has a two-fold objective. To develop adequate analytical techniques for ship-resistance prediction, and to use these analytical tools to evaluate and improve hull-form designs. Emphasis is placed on a critical assessment of existing theories and on their extension to permit new applications to the study of lower-resistance hull-form designs. New analytical techniques will be developed as necessary. Two specific problems which are of immediate interest to the Navy have been investigated under this project. The wave resistance of a catamaran, and the added resistance of a ship in waves.
(*g*) For the catamaran, we have investigated its wave-making resistance in an initially undisturbed water. Effects of the crucial parameters such as the speed, hull-form geometry, distance between two hulls and camber, to the wave resistance are currently being investigated. A working tool for use in predicting the resistance and propulsion characteristics of catamarans with reduced water-plane area is presently being developed. As ships are normally operating in a wavy seaway, the added resistance of a ship in waves has a great practical importance. To study such an extermely complex flow problem, a theory employing a systematic perturbation analysis has been developed wherein contribution to added resistance due to the interaction between undulating sea and ship-generated waves will be carefully examined.

348-08539-520-22

ADDED DRAG DUE TO WAVES

(*b*) Naval Ship Systems Command.
(*c*) Jorgen Strom-Tejsen, Hugh Yu Yeh.
(*d*) Theoretical; applied research.
(*e*) Formulate a procedure for predicting the added resistance of ships due to irregular seas. Present analytical procedures for estimating added resistance due to waves (Maruo, Joosen, and Boese) will be examined and comparisons will be made with model test results. NAVSHIPRANDCEN computer programs for motion prediction will be utilized to develop a program for predicting the added drag due to waves. Model tests will be required to determine the limitation of predicting procedure formulated.
(*g*) A computer program using Maruo's theory for the prediction of added drag has been prepared. Correlation between model test results and analytical predictions has been carried out.

348-08540-250-00

POLYMER DRAG REDUCTION AND DEGRADATION STUDIES

(*c*) Dr. T. T. Huang, Hydrodynamics Branch.
(*d*) Experimental and theoretical work; basic research.
(*e*) Experimental characterization of polymer drag-reduction by pipe flow tests and shear degradation in rotating disk tests. Use of data to develop reliable drag-reduction prediction techniques for plates and bodies.
(*g*) Study to be completed in 1973.

348-08541-520-00

INVESTIGATION OF DRAG OF APPENDAGES OF NAVAL SHIPS

(*b*) Naval Ship Systems Command.
(*c*) C. J. Wilson.
(*d*) Experimental; applied research.
(*e*) Provide a reliable procedure to predict the drag, interference effects and scale effects of a ship's appendages. Ship appendages refer usually to elements outside the main hull such as shafting, shaft supporting struts and strut barrels, bossings, power transmission struts and pods, bilge keels, stabilizer fins, rudders, and other control surfaces. These different arrangements are divided into a number of typical representative configurations and an adequate empirical formula derived for each category. These formulas are correlated with previous ship-model resistance tests conducted at NAVSHIPRANDCEN. Whenever available, existing information will be utilized to get interference effects and possibly new experiments will be conducted to determine missing interference factors.
(*g*) An interim set of empirical equations predicting the Reynolds number dependent components of appendage drag has been developed and computerized.
(*h*) **An Investigation of Appendage Drag–Prediction of Resistance, Effects of Interaction and Scaling Techniques,** M. P. Lasky, *NAVSHIPRANDCEN Rept. 3775* (in review).

348-08542-520-00

SHIP RESISTANCE COMPONENTS

(*c*) Dr. T. T. Huang, Hydrodynamics Branch.
(*d*) Experimental work primarily; applied research.
(*e*) Shear stress, pressure distribution, wake velocity, streamlines, and waves are being measured for a Series 60/Block 60 surface ship model. The directionality of shear stress is determined from high aspect ratio hot films. The data will serve as a base for development and verification of resistance prediction techniques.
(*g*) Shear stress and pressure measurements completed.

348-08543-520-00

FRICTIONAL RESISTANCE OF SHIP ROUGHNESS

(*c*) P. Granville or J. Power, Hydrodynamics Branch.
(*d*) Experimental work primarily; applied research.
(*e*) A large rotating disk facility has been built to obtain ship-scale skin friction. Analytical method will be used to translate disk torques to ship frictional resistance for various types of roughness.
(*g*) Rotating disk has been calibrated.
(*h*) **The Resisting Torque and Turbulent Boundary Layer of Rotating Disks with Smooth and Rough Surfaces,** P. Granville, *NAVSHIPRANDCEN Rept. 3711.*

348-08544-520-22

SPINNING CYLINDERS IN CONTROL SURFACE

(*b*) Naval Ship Systems Command.
(*c*) Mr. R. S. Dart, Ship Performance Department.
(*d*) Experimental; applied research.
(*e*) The feasibility of employing spinning cylinders in the trailing edges of submarine control surfaces to obtain lift with zero plane angle was determined experimentally with an approximately 15″ x 15″ control surface and 1.5-inch diameter cylinder.
(*g*) The test program has been completed, the data has been analyzed, and a report is being reviewed.

348-08545-520-22

APPENDAGE INFLUENCE ON THE FORCES ON A SUBMARINE

(*b*) Naval Ship Systems Command.
(*c*) Dr. C. M. Lee, Ship Performance Department.
(*d*) Experimental; applied research.
(*e*) The influence of the appendage combinations on the longitudinal normal force and pitching moment distributions was determined using a segmented model and conducting captive-model tests.
(*g*) The test program has been completed, the data has been analyzed, and the reports are being prepared.

348-08546-030-22

COMPUTATION OF HYDRODYNAMIC PRESSURE DISTRIBUTION ON A SUBMERGED BODY

(*b*) Naval Ship Systems Command.
(*c*) P. C. Pien.
(*d*) Theoretical; basic research.
(*e*) To develop a computer program based on the offsets of a given body to calculate the added mass, the hydrodynamic pressure distribution, the hydrodynamic force and moment for each degree of freedom of motion.
(*g*) Considering the closed wetted surface of the given body as a thin membrane which divides the infinite fluid into two portions, then every continuous irrotational motion may be regarded as due to a certain distribution of vorticity over this closed surface and is known from the motion of the body (as a first step, body motion is limited to a translation only). Since the unknown strength of such vorticity distribution can be expressed in terms of the known velocity inside the closed surface, it can be obtained by solving a simple nonsingular integral equation. Knowing the velocity on the inside surface and the vorticity, we can obtain the velocity on the outside surface by a simple addition. From this velocity distribution the hydrodynamic pressure distribution can be computed by Bernoulli's equation. If the body is under acceleration, the additional pressure distribution can also be obtained quickly from the time rate of change of the vorticity distribution.
(*h*) **Potential Flow About a General Three-Dimensional Body,** P.C. Pien, M. S. Chang, *NAVSHIPRANDCEN Rept. 3608* (in preparation).

348-08547-520-22

APPLICATION OF STOCHASTIC PROCESSES TO THE PREDICTION OF SHIP PERFORMANCE

(*b*) Naval Ship Systems Command.
(*c*) E. Neal.
(*d*) Theoretical; applied research.
(*e*) Develop and implement statistical procedures for predicting the propulsive performance of ships in irregular waves. It is known that the response of a ship to an irregular sea input may be assumed linear with respect to various motions. This fact can be exploited to predict the motions of ships by the use of well-known techniques from the linear theory of random processes. However, the propulsive response of ships in waves is not linearly proportional to wave height. Thus additional analysis procedures must be employed to successfully predict propulsive responses such as power, torque, and added resistance. This project entails the determination and development of adequate tools for predicting such responses. Existing statistical tools from multivariate spectral analysis are applicable to this work.
(*g*) The details of a statistical analysis procedure to predict added resistance in waves have been outlined. A computational scheme is currently being developed to implement the prediction technique.

348-08548-520-22

DESIGN METHODS FOR STABILITY AND CONTROL OF NAVAL SURFACE SHIPS

(*b*) Naval Ship Systems Command.
(*c*) Mr. E. E. Zarnick, Ship Performance Department.
(*d*) Theoretical, experimental; applied research.
(*e*) Develop theoretical methods for predicting the directional stability and maneuvering characteristics of naval ships for use by the designers. Systematic captive model experiments will be conducted on several models representing

different ship classes to determine the separate contributions of hull, rudder(s), skeg(s), and propellers to the static, rotary and acceleration coefficients in the equations of motion. Segmented model tests will be conducted to determine the hydrodynamic load distribution along the length of a surface ship hull as an aid in formulating an analytical approach for computing the stability derivatives. Analytical techniques will be developed to compute the coefficients in the equations of motion including the contribution of various appendages, based upon the results of the captive model tests. The equations of motion will be used to predict the stability and maneuvering characteristics of various ships and validated by comparison with model and full scale results.

(*g*) A model of the DL-2 Class has been selected as representing one of three surface ships to be studied. Modifications have been made to the model to investigate separate contributions of hull, rudder, skegs, propeller and sonar dome. Straight line testing has been completed. A report is in preparation.

348-08549-520-00

SEAKEEPING-SHIP MOTION PREDICTION

(*c*) Dr. N. Salvesen, Hydrodynamics Branch.
(*d*) Theoretical work; applied research.
(*e*) Development of new and improved methods and computer programs for prediction of ship seaworthiness. Emphasis is currently on course-keeping of ships in bow seas.
(*g*) Study to be completed in 1973.

348-08550-520-22

NAVSHIPRANDCEN SHIP MOTION AND SEA LOAD PROGRAM

(*b*) Naval Ship Systems Command.
(*c*) Dr. N. Salvesen, Ship Performance Department.
(*d*) Theoretical; applied research.
(*e*) To upgrade, extend, and verify the 6 degree of freedom NAVSHIPRANDCEN Ship Motion and Sea Loads Program to make it a useful tool for the naval architect in determining the seaworthiness and structural loads of ships. The following program modifications, extensions and verifications were carried out. Modify input/output format to ensure compatibility with additional programs that will use transfer functions of 6-degree program as input; improve roll prediction technique by providing alternative procedures for developing roll damping; and develop both long and short crested irrgular sea ship response subroutines using only transfer functions of 6-degree program as input.
(*f*) Completed.
(*g*) A report describing the roll damping procedures was issued.

348-08551-520-22

PREDICTION OF ROLL MOTION IN IRREGULAR SEAS

(*b*) Naval Ship Systems Command.
(*c*) Mr. A. G. Baitis, Ship Performance Department.
(*d*) Experimental; applied research.
(*e*) Determine the influence of hull form, loading, damping, ship speed and heading on the rolling motions of ships in irregular seas. The NAVSHIPRANDCEN Ship Motion and Sea Load Program was used to compute the effect of parametric variations (maximum section coefficient C_x, beam draft ratio B/T, transom width ratio T_w/B, transverse GM, and bilge keel size, speed, and heading) on roll. Model tests for crucial combinations of parameters were performed to verify the validity of the trends found from the computed roll data.
(*g*) A procedure for improving roll predictions in regular waves based on measured calm water damping coefficients was developed. A procedure for extending regular results into irregular waves was developed and checked with experimental model test results. Three reports were issued. The first reported on the influence of speed, heading, GM and damping variations. The second reported on the effectiveness of new roll damping calculation procedures in improving roll predictions. The third reported on the comparison between theoretical and experimental roll.

348-08552-520-22

LONG-TERM SHIP MOTIONS AND SEA LOADS

(*c*) Dr. W. E. Cummins or Dr. M. S. Chang.
(*d*) Theoretical work; applied research.
(*e*) Development of techniques for long-term statistical estimates of ship performance in the ocean. Initial work has been on two-parameter definition of sea spectra, assuming linear ship response.

348-08553-520-22

SHIP FLARE IMPACT STUDIES

(*b*) Naval Ship Systems Command.
(*c*) Mrs. M. D. Ochi, High-Performance Craft Branch.
(*d*) Experimental; applied.
(*e*) Drop tests were performed on five two-dimensional models representing systematic changes in ship hull form in order to clarify the fundamental nature of flare impact.
(*g*) Pressures in the area of the flare and body deceleration were measured and the impulse obtained. It was found that the spike type pressures (large peaks but short duration) that are important for ship bottom slamming contribute little to the impulse generated by flare impact.

348-08554-530-00

HYDROFOIL DESIGN METHODS

(*c*) Dr. T. Langan, Dr. K. Kerney, or Dr. H. Wang, Hydrodynamics Branch.
(*d*) Theoretical work; applied research.
(*e*) Evaluation and development of methods for prediction of forces, moments, and pressures on subcavitating hydrofoil systems. Lifting-surface methods and generalized lifting-line theories are to be evaluated. The emphasis is on hydrofoil-strut hydrodynamics interactions and their effect on structural design.
(*g*) Preliminary evaluation of lifting-surface methods has been completed.

348-08555-520-22

STUDIES ON THE MOTIONS AND HYDRODYNAMIC LOADS OF NAVAL CATAMARANS

(*b*) Naval Ship Systems Command.
(*c*) Mr. G. G. Cox, Ship Performance Department.
(*d*) Theoretical, experimental; applied research.
(*e*) Develop techniques for prediction of motion characteristics and hydrodynamic loads on structures of catamarans, and to validate the techniques by means of model experiments. An analytical method has been developed and reported for prediction of two-dimensional added mass and damping of arbitrary shape twin bodies in heave. Heave oscillation and restrained model tests have been performed and reported. A computer program has been developed to predict heave and pitch in head waves. The predictions of this program have been verified for conventional catamaran hulls. Model seakeeping tests have been performed, analyzed, and reported. Oscillation tests on two-dimensional twin bodies in roll and sway have been completed and reported. A prediction theory for the added mass and damping of twin bodies in sway and roll has been completed and reported. Equations have been derived and programmed to predict heave, sway and roll of catamarans in beam seas together with hydrodynamic loads.

348-08556-520-00

VISCOUS DAMPING IN HEAVE FOR HIGH SPEED CATAMARANS OF MODIFIED FORM (MODCAT)

(*c*) Mrs. M. D. Ochi, High-Performance Craft Branch.
(*d*) Theoretical and experimental; applied.

(*e*) To obtain the effect of scale and speed on the viscous contribution to heave damping, two scale models of MODCAT 1 will be oscillated over a range of frequencies and amplitudes at various forward speeds. Comparison of the experimentally obtained values with those computed analytically provides a measure of the viscous damping due to eddying that must be included in the theory for calculation of motions of MODCAT type hull forms.
(*g*) Tests are planned for April 1972.

U.S. NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER, PASADENA LABORATORY, 3202 E. Foothill Blvd., Pasadena, Calif. 91107. Commander.

350-07219-550-22

PROPULSOR DESIGN

(*b*) Naval Ordnance Systems Command.
(*c*) D. M. Nelson, Code 2542.
(*d*) Theoretical, experimental; applied research.
(*e*) Develop advanced theoretical methods for the design of underwater propulsors, to program them for high speed computers, and to apply them to the design of hardware which may be experimentally verified. Work to date has concentrated on the development of a lifting-surface design method for counter-rotating propellers operating on an axisymmetric body.
(*g*) The theoretical development and computer programming of the design method is complete. Two sets of counter-rotating propellers have been designed and fabricated. Testing the propellers has been carried out. The first design of counter-rotating propellers has been successfully tested at sea with limited instrumentation. They demonstrated acceptable torque balance as vehicle dynamics during water entry, startup, and full speed operation was good. Results from the propulsion tests of the second design of counter-rotating propellers indicate the following conditions when operating at design thrust coefficient. Advance ratio 3.6 percent greater than design value; propeller efficiency 2.0 percent greater than design value; and torque unbalance of + 2.5 percent. This set of propellers has five blades forward and six blades aft and a shorter hub (5.3 inches as compared to 7.0 inches) than the first design. They exhibit a propulsive efficiency (tow drag times forward velocity divided by shaft power) of approximately .93 when propelling the body.

350-07221-160-20

FLOW NOISE PIPE FLOW STUDIES

(*b*) Office of Naval Research.
(*c*) J. M. Caraher, Code 2542.
(*d*) Experimental, basic research.
(*e*) Study the effect of dissolved polymers on wall pressure fluctuations.
(*g*) A 4-inch pipe flow facility has been installed. This blowdown facility is being used with both tap water and solutions of polymers in tap water to study the effect of dissolved polymers on wall pressure fluctuations. Spectral and correlation analysis will be used to show the effect of polymer additives on the power spectral density of pressure fluctuations, on convection velocities, and on disturbance decay rates. Runs were made using the Robertshaw controller to provide constant flow speed and constant speed intervals of about 8 seconds were obtained. Unfortunately, there was much scatter in the data due to air rushing noise. More runs were then made with the control valve wide open and with the flow controller deactivated. The runs were made with water and with 200 ppm (by weight) of Polyox WSR-301. Air rushing noise was eliminated at the price of a decelerated flow. Data was obtained from 100 Hz to 10 kHz. Spectra obtained were smooth and regular when the data were plotted together in a normalized form; the curves for Polyox solutions were seen to be at least 2 dB below that for water and in some places as much as 5 dB below.

350-08557-250-20

BIOLOGICAL ASPECTS OF DRAG REDUCTION

(*b*) Office of Naval Research.
(*c*) P. R. Kenis, Code 2542.
(*d*) Experimental.
(*e*) Study the various biological aspects of drag reduction.
(*g*) A study of the shear-degradation resistance of bacterial polymers compared with synthetic materials indicates that natural polymers are more resistant to severe degradation than poly(ethylene oxide), but not as stable as polyacrylamide solutions. A summary report on all work on algal and bacterial polymers as friction-reducing materials has been issued (NUC TP 240). Work on the frictional properties of marine and fresh-water fish slimes has indicated that most fish exude a highly drag-reducing mucus. Drag-reducing exudates are also found in many marine benthic algae and the phytoplankton. A series of investigations has begun on the long-range oceanic pollution problems which might be caused by extensive Navy use of synthetic drag-reducing polymers. No short-term deleterious effects of concentrations as high as 100 ppm poly(ethylene oxide) have been noted using a variety of marine organisms as test species. Long-term studies using many generations of animals are now underway to identify any gross genetic effects of exposure to drag-reducing polymers.
(*h*) **Turbulent Flow Friction Reduction Effectiveness and Hydrodynamic Degradation of Polysaccharides and Synthetic Polymers,** P. R. Kenis, *J. Appl. Polymer Sci.* **15**, p. 607-618, 1971.
High Molecular Weight Algal Substances in the Sea, J. W. Hoyt, *Marine Biology* **7**, 2, p. 93-99, Oct. 1970.
Friction Reduction by Algal and Bacterial Polymers, P. R. Kenis, J. W. Hoyt, *NUC TP 240*, June 1971.
Fluid Friction of the Slime of Aquatic Animals, M. W. Rosen, M. E. Cornford, *NUC TP 193*, Nov. 1970.
Pollution Potential of Drag-Reducing Polymers, R. H. Wade, *NUC Symp. Environmental Preservation*, *NUC TP 215*, May 1971.

350-08558-230-20

EFFECT OF POLYMER ADDITIVES ON JET CAVITATION

(*b*) Office of Naval Research.
(*c*) J. W. Hoyt, Code 2501.
(*d*) Experimental.
(*e*) Study the effect of polymer additives on jet cavitation.
(*f*) The effect of dissolved high polymer materials on cavitation inception is being studied in a submerged underwater jet. Cavitation inception is determined using a hydrophone sensitive in the 1/2-20 kHz region. Concentrations of poly(ethylene oxide) WSR-301 from 1/2 to 80 ppm are employed both in the jet and the reservoir into which it discharges.
(*g*) The cavitation inception parameter is reduced markedly by the presence of poly(ethylene oxide); 1/2 ppm being detectable. At 70 to 80 ppm the inception index is only half that of pure water. These results were not markedly influenced by changed turbulence levels upstream of the nozzle; in contrast the inception index of the plain water jet was increased by increased turbulence ahead of the nozzle. The polymer also reduced the surface tension of test fluid; nevertheless the inception index was greatly reduced.
(*h*) **Effect of Polymer Additives on Jet Cavitation,** J. W. Hoyt, *Proc. 16th Amer. Towing Tank Conf.*, Sao Paulo, Brazil, 1971.
Jet Cavitation in Polymer Solutions, J. W. Hoyt, *Proc. ONR Drag Reduction Workshop*, Boston, 1970.
Cavitation Suppression and Stress Effects in High-Speed Flow of Water with Dilute Macromolecule Additives, A. T. Ellis, J. G. Waugh, R. Y. Ting, *J. Basic Engrg.*, Sept. 1970.

350-08559-250-22

POLYMERIC DRAG REDUCTIONS; PRINCIPLES AND TECHNIQUES

(*b*) Naval Ships Systems Command, Naval Ordnance Systems Command.
(*c*) D. M. Nelson, NUC, Code 2542.
(*d*) Experimental and theoretical.
(*e*) The main emphasis of this project is on improving the prediction of the effectiveness of polymeric drag reduction systems on marine vehicles, using theory as much as possible, especially turbulent boundary layer theory. Fire-fighting applications of polymeric friction reduction are also a side-line interest.
(*g*) Work with M. Poreh's model of wall roughness effect has led to some useful insight and indicated the need for further work. Improvements have been made in the prediction of polymer concentration on the afterpart of bodies of revolution where the approximation of a boundary-layer thickness that is small compared with body radius is no longer valid. A survey of the maximum fire-fighting benefits of polymeric friction reduction has been made and submitted for publication.
(*h*) **Drag Reduction of Flat Plates with Surface Roughness,** M. Poreh, *NUC TP 222*, Apr. 1971.

350-08560-250-22

POLYMER EFFECTS ON STREAM COHERENCE

(*b*) Naval Ships Systems Command.
(*c*) James H. Green, NUC, Code 254.
(*d*) Experimental.
(*e*) Wind causes early breakup of water streams during fire fighting, and this is a prevailing condition on ship decks. The purpose of this work is to study the effect of dissolved polymers on the coherence of water streams as they exit from nozzles. Small diameter streams (one water and one polymer solution) are studied and compared as they exit from two identical side-by-side nozzles. Sampling cans are used to measure the throw and dispersion patterns.
(*f*) Inactive.
(*g*) Tests were conducted with two nozzle designs (1/4- and 1/2-inch tips). Substantial improvements were obtained with the smaller tip only. It is suspected that the effect is reduced as the nozzle performance with plain water is better to start with.
(*h*) **Effect of Polymer Additives on Nozzle Stream Coherence: A Preliminary Study,** J. H. Green, *NUC TN 504*, Mar. 1971.

U.S. NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER, San Diego, Calif. 92132. Commander.

351-07225-450-00

SEAWATER HYDRAULIC TOOLS

(*c*) R. A. Nelson, Code 6514.
(*d*) Experimental; developmental.
(*e*) Investigate, modify and test certain existing commercial hydraulic and pneumatic units that show possibilities of adaptation as low-pressure seawater-powered motors and associated equipment. To develop low-pressure seawater-powered rotary actuator and hydraulic system ancillary equipment. Develop under-water systems such as hydraulically operated tools and handling devices.
(*f*) Suspended.
(*g*) Power and torque curves were developed for a seawater powered low pressure turbine hydraulic motor. A 100-hour life test was completed with no measurable effect on turbine performance.
(*h*) **Test of a Seawater Operated Turbine,** *NUC TN 621*, Oct. 1971.

NAVAL UNDERWATER SYSTEMS CENTER, DEPARTMENT OF THE NAVY, Newport, R.I. 02840. Captain Robert T. Lundy, Commanding Officer; Harold E. Nash, Technical Director.

352-06266-160-00

HYDRODYNAMIC NOISE

(*c*) Dr. Howard H. Schloemer.
(*d*) Experimental and theoretical; applied research.
(*e*) Experimental investigations are being conducted in an acoustic water tunnel to determine the statistical properties of boundary pressure, such as power spectrum, longitudinal and lateral cross-spectra, diagonal correlations and transducer size and shape effects. All sensors are mounted flush to the wall. Experimental results are compared to theoretical predictions. With these studies it is hoped to be able to more completely describe the noise field produced by turbulent flow. A new rectangular test section 12 inches wide and 4 inches high was recently added to the water tunnel for flow-induced noise investigations.
(*g*) The discrimination of boundary-layer pressure fluctuations by transducers of various shapes was examined experimentally in the acoustic wind tunnel. These results verified previously published theoretical predictions. In the mid-frequency range, transducers that have their longest dimension parallel to the flow produced the greatest discrimination against pressure fluctuations. At high frequencies, the response becomes a function of size and independent of shape, as predicted. Theoretical studies continued in the direction of understanding the flow-induced noise problem. These dealt with a comparison of turbulent-flow induced, plate-vibration statistics computed for mathematical models of finite and infinite thin plates. Studies are continuing on the effect of heavy fluid loading on the vibration statistics of finite plates excited by turbulent flow and the corresponding acoustic radiation.
(*h*) **Measured Discrimination of Boundary-Layer Pressure Fluctuations by Round, Square, and Rectangular Transducers,** E. C. Recine, *J. Acoust. Soc. Am.* **51**, 1, (Part 2), pp. 369-377, Jan. 1972.

352-07555-450-00

OCEANOGRAPHIC TURBULENCE RESEARCH

(*c*) A. T. Massey, Research Oceanographer.
(*d*) Field investigation; basic research.
(*e*) The determination of the spatial and temporal structure of the fluctuating velocity, pressure, temperature and salinity fields associated with turbulent processes in the mixed surface layer of the ocean; the examination of the balance between the time rate of change of the energy (variance) and the rates of energy production, dissipation and diffusion for the fluctuations in velocity, temperature and salinity; the investigation of the interaction between turbulent quantities and synoptic oceanographic and meteorological variables (temperature, salinity and velocity profiles, and air-sea interface condition).
(*h*) **Dissipation of Kinetic and Thermal Energy in the Mixed Surface Layer of the Ocean During BOMEX,** *NUSC Rept. No. 4180.*

352-08561-020-00

APPLICATION OF TURBULENCE DEFORMATION THEORY TO PRESSURE PROBES

(*c*) Dr. L. Goodman, Res. Physicist; A. T. Massey, Res. Oceanographer.
(*d*) Theoretical and experimental research; applied research.
(*e*) A theoretical analysis has been carried out on the deformation effect of a body on a uniform turbulent stream flowing past the body. The theory has been used to relate dynamic pressure fluctuations induced on the body to the undeformed velocity fluctuations (the velocity fluctuation for upstream of the body). Wind tunnel experiments examining the above relationship for various shaped bodies are underway.
(*g*) Deformed and undeformed two-point turbulent velocity correlations are linearly related and analogous to the

celebrated Cauchy vorticity equation. Theoretical analysis suggests that for a two-dimensional body dynamic pressure fluctuations are related to velocity fluctuations analogously to how current fluctuations are related to voltage fluctuations in an RC circuit. Preliminary wind tunnel tests on three-dimensional bodies tend to confirm this relationship.

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U.S. NAVAL WEAPONS LABORATORY, Dahlgren, Va. 22448. Dr. W. G. Soper, Research Associate, Code GR.

353-07073-510-00

ENTRY PROBLEM FOR BLUNT WEDGES AND CONES

(*d*) Theoretical; applied research.
(*e*) Solutions are to be obtained for the flow fields around blunt wedges and cones entering a compressible fluid half-space. Results will be applied to the design of penetrating projectiles.
(*f*) Suspended.
(*g*) The governing equation has been found to be a non-linear, second-order, elliptic partial differential equation in two similarity variables. Approximate numerical solutions for the wedge have been obtained.

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TENNESSEE VALLEY AUTHORITY, ENGINEERING LABORATORY, Drawer E, Norris, Tenn. 37828. Rex A. Elder, Laboratory Director.

354-06712-060-00

WATER QUALITY STUDY–HYDRODYNAMICS OF A DENSITY-STRATIFIED RESERVOIR

(*d*) Field investigation; basic research.
(*e*) Investigations continued into the influence of water movements through reservoirs on water quality in the presence of temperature stratifications. Also investigated were the causes of temperature stratifications, especially heat exchange through the water surface. Simplified graphical and mathematical models were developed to simulate, in a broad way, the processes involved. After a general probing into the problems of reservoir and stream thermo-hydrodynamics, additional withdrawal layer measurements were made in 11 reservoirs to improve the preliminary prediction equations on withdrawal layer thickness and flow distribution as functions of density gradient, discharge, distance from the dam, reservoir geometry and intake location.
(*f*) Data evaluation and analysis are in progress.
(*h*) **Prediction of Withdrawal Layer Thickness in Density Stratified Reservoirs,** R. A. Elder, W. O. Wunderlich, presented at the *13th Congr. Intl. Assoc. Hydraul. Res.*, Kyoto, Japan, Aug. 1969.
Field Measurement Techniques in Large Reservoirs, B. E. Johnson, W. O. Wunderlich, *Proc. 9th Ann. Environmental and Water Resources Engrg. Conf.*, Vanderbilt Univ., Nashville, Tenn., June 1970.
Effect of Intake Elevation and Operation on Water Temperature, W. O. Wunderlich, R. A. Elder, *J. Hydraul. Div., Proc. ASCE*, HY6, Paper 6917, Nov. 1969.
The Water Temperature Regime of Fully-Mixed Streams, W. O. Wunderlich, presented to *ASCE Hydraul. Div. Specialty Conf.*, Utah State Univ., Logan, Utah, Aug. 1969.
Discussion of a Paper Entitled Selective Withdrawal from Density-Stratified Reservoirs, W. O. Wunderlich, R. A. Elder, Discussion of *Proc. Paper 6702*, HY5, May 1970, by N. H. Brooks and R. C. Koh, J. Hydraul. Div. Proc. ASCE, July 1969. Thirty-six internal reports were issued.

354-06716-340-00

WHEELER PROJECT–UNITS 9-11 VIBRATION STUDIES

(*d*) Field investigation.
(*e*) At certain gate positions the unusual vibrational behavior of Units 9, 10 and 11 is basically manifest in three areas. The shaft performs complex whirls and gyrations which can be observed visually; the powerhouse structure and auxiliary equipment in the vicinity of these units vibrate to the extent that the vibrations are felt; and the vibrations of the rotating machinery and the auxiliary equipment can be heard, and are combined with flow-generated sounds to create a high noise level in the vicinity of the machine. After the turbine manufacturer completed several design changes a series of comprehensive tests was conducted on the behavior of Unit 11 to define the sources of the objectionable shaft motions, the noise and the structural vibrations; find and evaluate the most obvious critical stresses in the various parts of the machine and its bearings; evaluate the effect of the vibratory loading that the machine is imparting to the surrounding powerhouse structure; and evaluate the effectiveness of the various modifications made to the unit by the turbine manufacturer.
(*f*) Completed.
(*g*) The studies resulted in the removal of all operational restrictions with the provision that more frequent and more detailed inspection be performed.
(*h*) **Field Measuring Techniques for Hydraulic Turbine Vibrations,** R. A. Elder, S. Vigander, *IAHR 13th Congr., Intl. Assoc. Hydraul. Res.*, Kyoto, Japan, 1969. Two internal reports were issued.

354-06723-340-00

RACCOON MOUNTAIN PUMPED-STORAGE PROJECT–INTAKE-OUTLET IN UPPER RESERVOIR

(*d*) Experimental; for design.
(*e*) A 1:100 scale model of the upper reservoir was constructed to develop an inlet-outlet structure that would provide overall satisfactory operating conditions including freedom from air-drawing vortices for the operating range. Generally, the vortex problems were created by the combined effect of excessive surface circulation, the large tunnel and large discharge rate.
(*g*) A 100-foot diameter semi-cylindrical silo-type intake was designed. The silo is about 230 feet high and is perforated by 117 rectangular openings eight feet wide by 16 feet high.

354-07080-340-00

RACCOON MOUNTAIN PUMPED-STORAGE PROJECT–HYDRAULIC TRANSIENT STUDIES

(*d*) Applied research; for design.
(*e*) Hydraulic transient studies are being conducted to provide information regarding waterhammer and surge magnitudes for designs of the strength of the piping system and associated hydraulic machinery and for sizing of the surge tank. A numerical model was developed for these studies. The model describes the detailed branching tunnel geometries in the vicinity of the powerhouse. This was accomplished by adopting a scheme that combines the method of characteristics and the implicit method. The program is capable of investigating all feasible machine operating conditions, including sequential unit operations. The machine characteristics were obtained from model tests performed by the manufacturer. The studies also include determinations of the natural frequencies of the hydraulic system. The purpose of this study is to identify possible resonance frequencies should some periodic forcing function exist and to explore the possibility of avoiding such resonance phenomena. A program using the transfer matrix technique is being developed for this study.
(*h*) Eight internal reports were issued.

354-07081-340-00

RACCOON MOUNTAIN PUMPED-STORAGE PROJECT–INTAKE-OUTLET IN LOWER RESERVOIR

(*d*) Experimental; for design.
(*e*) Nickajack Reservoir, which serves as the lower reservoir

for the Raccoon Mountain Project is a navigable waterway; at the plant site it is about 600 feet wide and 100 feet deep. Without proper controls, localized currents and turbulence, created by operation of the project, could cause conditions hazardous to navigation. To develop an inlet-outlet structure which would eliminate these hazards, a 1:90 scale model of a one-mile reach of the reservoir was constructed. Provisions were made to produce typical discharge hydrographs for the pumped-storage plant and for the flows through the reservoir by means of a digital computer. A scale-model, remote-radio-controlled tow was used to evaluate navigation conditions associated with the various proposed inlet-outlet structures.

(*g*) A satisfactory inlet-outlet structure was developed which eliminated the navigational hazards.

354-07082-340-00

BROWNS FERRY AND SEQUOYAH NUCLEAR PLANTS–HYDRODYNAMIC FORCES ON SUBMERGED DIFFUSER PIPES

(*d*) Applied research; for design.

(*e*) Condenser cooling water from the Browns Ferry Nuclear Plant will be mixed with the flow in Wheeler Reservoir by means of three large diameter (20.5, 19, and 17-foot) corrugated metal pipes, half buried across the main navigation channel of the reservoir. To design adequate anchorages for these diffusers, laboratory investigations were undertaken to measure the hydrodynamic forces existing on these diffusers. Forces resulting from the passage of barge trains over the diffusers were measured. The effect of flood flows was determined by measuring lift and drag coefficients over a range of Reynolds numbers for various pipe and backfill configurations. The effect of barge trains was determined by constructing a towing tank 140-feet long by 35-feet wide; and towing a 1:20-scale barge train over a diffuser of the same scale instrumented to measure vertical and horizontal forces. Variables in these tests include towing speed, length and width of barge train, reservoir depth, and flow velocity. These tests indicated that forces resulting from barge trains were considerably greater than forces from flood flows, possibly as high as 10,000 to 15,000 pounds per foot of pipe depending upon the type of backfill material used. Further evaluation is under way on the effects of backfill material on anchorage requirements. A test facility is utilized in which pipes, which are half buried in selected backfill materials, are subjected to forcing functions as determined from the towing tank tests.

(*f*) Completed.

(*g*) From the studies it was concluded that hydrodynamic forces acting on a half-buried diffuser pipe caused by barge passage increase with an increase in river flow velocity, pipe diameter, barge width and barge draft; and a decrease of barge length and pipe submergence. For the given barge and channel geometries tested and under no flow conditions, the maximum lift and drag occurred at a Froude number of about 0.7 where the Froude number is based on the velocity of the barge and the depth of the reservoir. It was determined that the maximum lift and drag on the Browns Ferry diffusers will be about 15,000 pounds per linear foot; at Sequoyah the maximum lift will be about 5000 pounds per linear foot and the maximum drag of about 3000 pounds per linear foot.

(*h*) **Hydrodynamic Forces on Diffuser Pipes Due to Barge Passage,** S.-T. Hsu, E. E. Driver, R. A. Elder, *Proc. 14th Cong. Intl. Assoc. Hydraul. Res.* **2**, pp. 109-116, 1971. One internal report was issued.

354-07083-870-00

BROWNS FERRY NUCLEAR PLANT–CONDENSER-WATER THERMAL DIFFUSION IN A THREE-DIMENSIONAL MODEL

(*d*) Applied research; for design.

(*e*) Condenser cooling water from the Browns Ferry Nuclear Plant will be mixed with the flow in Wheeler Reservoir by means of three diffuser pipes. Flow through Wheeler Reservoir is controlled by two hydro-projects–Wheeler and Guntersville Dams. These projects are operated for peaking power purposes and, as a result, flows in Wheeler Reservoir are highly variable. To evaluate the effects of operations of these two hydro-projects and Browns Ferry on the thermal regime of Wheeler Reservoir, a distorted scale model, 1:250 horizontal and 1:50 vertical, will be constructed. Operation of the model will be under control of a digital computer and will be capable of simulating both steady and unsteady flows. Three hundred thermisters connected to the computer through a crossbar scanner will be used to collect and analyze temperature data.

(*g*) Test results have determined the relationship between the temperature reduction achieved by the diffuser mixing and the magnitude of a steady river flow. The three-dimensional distributions of velocity and temperature in the model have been measured for evaluation of thermal effects.

354-08562-340-00

RACCOON MOUNTAIN PUMPED-STORAGE PROJECT–LOWER RESERVOIR TRASHRACK VELOCITY DISTRIBUTION STUDIES

(*d*) Applied research; for design.

(*e*) Studies will be conducted to develop a trashrack structure at the inlet-outlet to Nickajack Reservoir which will perform satisfactorily under the expected hydrodynamic loads. The possibilities of resonances, hydroelastic interactions and excessive vibrations will be investigated by theoretical and experimental methods. The experimental tests will include a 1:40 scale model to check pier and trashrack design in regard to the overall flow field and a 1:2 scale model to investigate vibrational problems.

(*g*) By determining the proper dimensions for the structure a satisfactory velocity distribution was developed. One internal report was issued.

354-08563-350-00

BEAR CREEK PROJECT–LITTLE BEAR CREEK DAM

(*d*) Applied research; for design.

(*e*) Model studies were required for the spillway structure to determine the design which would provide the required discharge-headwater elevation characteristics, a design which would result in the minimum chute side wall heights, and the wave heights and velocities in the downstream basin. A 1:36 scale model was designed and constructed. The approach topography was modeled for approximately 400 feet upstream from the site and for approximately 300 feet on each side of the chute centerline. The basin below the chute was modeled for approximately 500 feet downstream from the chute.

(*f*) Completed.

(*g*) The original design consisted of a slotted, ungated, radial chute spillway. Tests indicated that the slot performed as desired but, for flows over the main crest, approximately 1.5 ft of additional head was required above that specified. Standing waves in the chute which would have overtopped the proposed walls were generated by the abrupt expansion of the super-critical flow passing over and through the low-level slot and were also due to the separation of the approach flow passing around the upstream bridge piers and over the ends of the upstream retaining walls. Testing indicated a quadruple low-flow slot design along with reorientation of the upstream retaining walls and the bridge piers, would achieve satisfactory discharge characteristics. Nine internal reports were issued.

354-08564-870-00

RESEARCH ON DESIGN OF SYSTEMS FOR WASTE MANAGEMENT

(*d*) Experimental; for design.

(*e*) To provide more economic and efficient industrial waste

management alternatives, investigations were begun of a concept for simultaneous transportation and combined treatment of solid, liquid and gaseous wastes from several sources. To determine the technical and economic feasibility of the concept the following investigations were undertaken; Literature studies of industrial waste compatibility; modest cost comparisons of integrated and separate waste treatment systems; literature studies and bench scale experiments using air, water and particulates to study multi-phase flow mechanics; and experimental studies of scrubbing waste gases in a transportation conduit.

(*f*) Continuing.

(*g*) Preliminary results indicate that integrated transportation and centralized treatment of wastes may be, under the proper circumstances, economically and technically feasible. The concept has enough merit to warrant additional studies including a pilot scale test.

(*h*) **A Concept of Integrated Waste Transportation and Treatment,** S. Vigander, presented at *10th Ann. Environmental and Water Resources Engrg. Conf.*, Vanderbilt Univ., Nashville, Tenn., June 1971.
Economics of Central Gas Cleaning, E. D. Harshbarger, presented at the *10th Ann. Environmental and Water Resources Engrg. Conf.*, Vanderbilt Univ., Nashville, Tenn., June 1971. Three internal reports were issued.

354-08565-340-00

PARADISE STEAM PLANT–COOLING TOWER DISCHARGE MEASUREMENTS

(*d*) Field investigation; operation.

(*e*) Tests were conducted to measure the discharge from cooling tower No. 2 in connection with the cooling tower acceptance tests. Measurements were made by the current method, the fluorescent tracer dye dilution method and the heat transfer method.

(*f*) Completed.

(*g*) Test results showed good agreement among the three methods with general variation up to 2.5 percent and some variations up to 6 percent.

354-08566-710-00

REMOTE SENSING TECHNIQUES

(*d*) Field investigation; applied research.

(*e*) The continuing use of open cycle condenser cooling systems for nuclear and fossil fuel electric power generating units and the increasing emphasis on maintaining good water quality created a need for a technique capable of measuring the three-dimensional water temperature distribution in large bodies of water within short time periods. This study investigated the feasibility of airborne infrared sensing in quantitatively determining water temperatures. Preliminary studies from 1967 to 1971 led to a year-long program which included regularly scheduled flights over existing and proposed plant sites in the TVA area as well as extensive collection of ground truth. The objectives of the program were to obtain information on the seasonal and daily temperature variations at the sites, to evaluate the accuracy with which water surface temperatures are measured by the infrared technique and to assess the feasibility of determining the sub-surface thermal regime by extrapolation from the surface temperatures.

(*g*) The results of the studies confirmed the capability of airborne infrared sensing in covering a wide area rapidly and producing a qualitative image of the surface thermal regime. Two inherent drawbacks of the technique as a tool for regular use in the field are the extreme dependence on acceptable flying and visibility conditions and the inability to measure temperatures below the water surface. In addition, the present state-of-the-art in infrared detector instrumentation and atmospheric absorption models indicates a quantitative accuracy of no better than 2°F which is unacceptable for many potential applications.

354-08567-750-00

VORTEX SCALING

(*d*) Basic research.

(*e*) A preliminary research program incorporating analytical and experimental studies has been initiated to improve upon the present limited information on vortex scaling. The primary objective of the analytical investigation is to develop a numerical model of an intake vortex with less restrictive assumptions than those in existence. The experimental study will provide actual measured data and verify the assumptions made in the numerical model. A 14-foot diameter, 2-foot deep tank was constructed for the experiments.

354-08568-340-00

RACCOON MOUNTAIN PUMPED-STORAGE PLANT–SURGE TANK JUNCTION

(*d*) Applied research; for design.

(*e*) The Hydraulic Transient Studies indicated that the ultimate surge magnitudes depend to great extent upon the headloss characteristics of the surge tank junction. The purpose of this study was to provide accurate headloss data for the transient computations. The surge tank geometry originally proposed was tested and it was found that the headloss created was insufficient and would result in excessive surge levels. The riser area was reduced by about 18 percent. The new surge tank geometry was found to yield acceptable surge and hammer magnitudes.

(*f*) Completed.

(*g*) The headloss coefficient varies greatly with the flow configuration and discharge ratio between the branches. The loss coefficient depends slightly upon Reynolds number. Two internal reports were issued.

354-08569-350-00

DUCK RIVER PROJECT–NORMANDY DAM

(*d*) Applied research; for design.

(*e*) A 1:100 scale model of the Normandy Dam was constructed to conduct an hydraulic analysis of the project, particularly to determine spillway capacity, approach flow conditions, apron efficacy and height of the training walls, wave height and velocities, water surface profiles and pressures on the training walls, and water surface profiles on the intermediate piers.

(*g*) Test results indicated that the proposed pier geometries cause persistent vortices in the pier vicinity and that the apron elevation is too high. Modifications will have to be made to the spillway details.

354-08570-860-00

FORT PATRICK HENRY AERATION STUDY

(*d*) Field investigation; experimental.

(*e*) Develop a practical, economical means of increasing the dissolved oxygen in TVA's streams and lakes. Preliminary studies indicate one possible method might be the direct application of oxygen gas in the form of tiny bubbles into the water immediately upstream from the dam. A small-scale test is underway using eight different commercial diffusers which generate small bubbles to check the applicability of such diffusers to field conditions. The diffusers, each with about one square foot of surface, and the oxygen supply manifold are situated near the bottom of the 65-foot deep Fort Patrick Henry Reservoir about 130 feet upstream from unit one centerline. The underwater unit hangs from a small steel barge which is moored at the site. The barge contains manual hoisting equipment to retrieve the underwater unit and pressure and flow measurement instrumentation. A liquid oxygen tank situated at the switchyard level supplies oxygen to the underwater unit through one-inch piping and flexible rubber hose. Another part of this study is the investigation of fouling of the diffuser surfaces under operating conditions. A special photo-

graphic box was constructed which permits the diffuser surfaces to be photographed under the same lighting conditions and at the same focus for comparison before and after operation. The second phase of this study, scheduled to begin in the fall of 1972, will be to define the optimum surface area of the chosen diffusers and their optimum location relative to the turbine intake. Measurements will then be taken to determine the aeration efficiency of the system and to define possible physical and mechanical effects of the oxygenated flow on the hydraulic turbines. Laboratory tests are being planned which involve the construction of a six-foot diameter, approximately 45-foot deep tank to study the effects of water depth on bubble behavior and absorption efficiency.

354-08571-870-00

BROWNS FERRY NUCLEAR PLANT–COOLING TOWERS

(*d*) Applied research; for design.
(*e*) To accommodate changes in the Alabama water temperature criteria, cooling towers are being considered in addition to the originally designed diffuser pipes for handling the condenser water from Browns Ferry Nuclear Plant. Depending upon the amount of river flow and water temperature, there will be three possible modes of operation of the cooling tower–diffuser pipe cooling system; Closed cooling by the cooling towers; river cooling by using the diffuser pipes; and helper cooling with both systems in series. To achieve these three types of operation three gate structures will have to be built to direct condenser flow from the pipes to the cooling towers and from the towers back to the pipes. A 1:39.5 scale model is being designed to study the overall performance of the proposed structures. A computer program was developed to investigate transient phenomena between the helper and closed modes.

354-08572-220-00

SEQUOYAH NUCLEAR PLANT–DIFFUSER PIPE SCOUR STUDY

(*d*) Applied research; for design.
(*e*) A 1:20 scale model was designed and constructed to determine the stone size required to prevent erosion near the diffuser pipe system.
(*g*) Preliminary results indicated that the most severe scour will occur near the dead end of the upstream pipe.

354-08573-870-00

SEQUOYAH NUCLEAR PLANT–CONDENSER WATER DIFFUSER STUDY

(*d*) Applied research; for design.
(*e*) The diffuser-underwater dam-skimmer wall system was designed to permit the plant to operate for a period of about three days of no flow without exceeding the Tennessee temperature criteria. The underwater dam which is situated between the diffusers and the skimmer wall will impound cold water to be used by the plant during periods of low or no flow and permits the reduction of the length of the skimmer wall. However, the dam cuts off the supply water for the diffusers that would have been available from upstream; it is possible, therefore, that temperatures in the region between the diffusers and the dam will exceed the criteria sooner than the downstream temperatures. To determine the time-temperature relationship as a function of the elevation of the dam crest, a two-dimensional mathematical model was developed and verified by a two-dimensional physical model.
(*f*) Suspended.
(*g*) Test results determined the dam crest elevation and skimmer wall effective opening which would permit the plant to operate for three days without exceeding the temperature criteria. Five advance reports were issued.

TENNESSEE VALLEY AUTHORITY, Hydraulic Data Branch, Knoxville, Tenn. 37902. Mr. Paul C. Spath, Branch Chief.

355-0259W-810-00

COOPERATIVE RESEARCH PROJECT IN WESTERN NORTH CAROLINA

For summary, see Water Resources Research Catalog **6,** 4.0206.
(*h*) **Watershed Research in Western North Carolina,** TVA and N.C. State Univ., Final Rept., June 1970.

355-0260W-810-00

WHITE HOLLOW WATERSHED

For summary, see Water Resources Research Catalog **6,** 4.0248.

355-0261W-810-00

PINE TREE BRANCH WATERSHED

For summary, see Water Resources Research Catalog **6,** 2.1304.

355-0262W-810-00

NORTH FORK CITICO CREEK RESEARCH WATERSHED

For summary, see Water Resources Research Catalog **6,** 4.0249.

355-0263W-810-00

UPPER BEAR CREEK EXPERIMENTAL PROJECT

For summary, see Water Resources Research Catalog **6,** 7.0192.

355-00765-810-00

EVAPORATION IN THE TENNESSEE BASIN

(*d*) Field investigation; applied research.
(*e*) To provide data for estimating reservoir losses and derive a general rule, applicable to the Basin, permitting computation of evaporation from pans at six locations in Basin, together with standard meteorological readings.
(*h*) Results published in monthly and annual bulletins, *Precipitation in Tennessee River Basin* (Project 00768).

355-00768-810-00

PRECIPITATION IN TENNESSEE RIVER BASIN

(*d*) Field investigation; basic research.
(*e*) A comprehensive study of rainfall and other weather phenomena for purposes of water dispatching and improvements in water control; storm studies as related to maximum precipitation, rainfall-runoff, spillway design and operation, etc.
(*h*) Monthly and annual bulletins, *Precipitation in Tennessee River Basin.*

355-00769-860-00

RESERVOIR AND STREAM TEMPERATURES

(*d*) Field investigation; basic research.
(*e*) Study of water utilization and water movement as concerns industrial and steam plant locations and stream pollution. Variations in temperature from surface to bottom in selected reservoirs are determined by soundings, and by continuous recording gages in selected natural streams. Periodic observations are made at gaging stations.

355-00771-350-00

GALLERY DRAINAGE IN LARGE DAMS

(*d*) Field investigations; design.
(*e*) Weirs are placed in main galleries and drainage measured as check on tightness and stability.

355-00779-810-00

MAXIMUM POSSIBLE PRECIPITATION IN TENNESSEE VALLEY

(*b*) Cooperative with U.S. Weather Bureau.
(*d*) Theoretical; applied research.
(*e*) Hydrometeorological analysis of large storms with upward adjustments of controlling factors to maximum limits as applied to the Tennessee Valley and subdivisions.
(*h*) **Probable Maximum and TVA Precipitation for Tennessee River Basins Up to 3000 Square Miles in Area and Durations to 72 Hours,** *Hydrometeorological Rept. No. 45*, U.S. Weather Bureau, May 1969.

355-00780-820-00

PERIODIC EVALUATION OF GROUNDWATER STORAGE

(*d*) Theoretical; operation.
(*e*) By analysis of current records of stream discharge, the volumes of runoff in groundwater and channel storage are determined for use in operation of multi-purpose reservoirs.
(*g*) Results reported weekly within the organization.

355-00785-350-00

SEDIMENTATION OF EXISTING RESERVOIRS

(*d*) Field investigation; design and operation.
(*e*) Selected ranges in reservoirs are probed and sounded, volumetric samples are collected and analyzed, quantity and distribution of sediment are computed to determine deposition by stream, probable life of reservoir, effect of sediment storage on navigation channels and sedimentation of down-stream reservoirs, and probable sedimentation in future reservoirs.
(*h*) **Sedimentation in TVA Reservoirs,** *Rept. No. 0-6693*, TVA, Feb. 1968.

355-07088-810-00

COAL STRIP-MINE WATERSHED DEMONSTRATION, JACKSON COUNTY, ALABAMA

(*d*) Field investigation; basic research.
(*e*) Determine the effects of coal strip-mining and subsequent reclamation upon the hydrologic response, water quality, and stream ecology of a small watershed. Observations include rainfall, runoff, sediment, water temperature, water quality, and stream ecology.
(*f*) Project began in 1968 with the installation of a weir and recording equipment for collection of basic data. Suspended January 1971 until such time as mining operations are scheduled.

355-07089-810-00

WATERSHED STUDIES OF FERTILIZER MOVEMENT

(*d*) Field investigation; basic research.
(*e*) The movement of nutrients in runoff from both fertilized and unfertilized forested and agricultural watersheds is being studied on six watersheds in the Tennessee Valley. These include five watersheds previously instrumented for other purposes and now modified to permit sampling for water-quality parameters.
(*f*) Fertilizer applications were made following calibration periods on two of the three agricultural watersheds. Forage samples were obtained to determine uptake of nutrients by pasture grasses. Proportional streamflow sampling is accomplished by mechanical splitter-type samplers or automatic pumping samplers. Subsequent fertilization on forested watersheds will be coordinated with management programs.
(*g*) Only preliminary results are available. Findings will be published in technical journals and project reports.
(*h*) **Nutrient Losses from Small Watersheds,** V. J. Kilmer, R. T. Joyce, presented at *Irrig. and Drainage Div. Specialty Conf., ASCE*, Miami Beach, Fla., Nov. 1970.
Fertilizer Use in Relation to Water Quality with Special Reference to the Southeastern United States, V. J. Kilmer, R. T. Joyce, July 1971.

355-08574-810-00

EFFECTS OF URBANIZATION UPON THE QUALITY AND QUANTITY OF STREAMFLOW

(*d*) Field investigation; basic research.
(*e*) Four watersheds in Knoxville with different types of urban development have been instrumented to provide rainfall, runoff, and water-quality measurements. Data will be used to assess the effect of different levels of urbanization upon water quantity and quality, and to develop techniques to predict the impact of urbanization upon these parameters.
(*f*) Data collection and manual sampling began in the spring of 1971. An automatic pumping sampler will be used at each of the sites to provide representative samples.
(*g*) Results will be reported in appropriate technical journals and project reports.

TENNESSEE VALLEY AUTHORITY, Water Resources Management Methods Staff, Knoxville, Tenn. 37902. Walter O. Wunderlich, Supervisor.

356-08575-800-00

DEVELOPMENT OF WATER RESOURCES MANAGEMENT METHODS

(*d*) Basic and applied; theoretical.
(*e*) The project will develop for the Tennessee River system comprehensive procedures which will allow current evaluation and consideration of all essential objectives, such as navigation, flood control, power production, water quality management, water supply and recreation. These procedures will increase TVA's capability to appraise system modifications and improve system operation. Upon completion, the methods will become day-to-day decision aids for TVA's water resource planning and management activities. They will expand the present decision-making processes by using more comprehensive and automated procedures which can respond to the steadily increasing complexities of water quantity and quality management and optimize the benefit derived from the region's water resource.

U.S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, Office of Research, Environmental Design and Control Division, Environmental Control Group, 4200 Connecticut Avenue, N.W., Washington, D.C. 20590.

357-07218-200-00

LABORATORY STUDY OF HYDRAULICS OF BRIDGE WATERWAYS AND SPUR DIKES

(*c*) Roy E. Trent, Ph.D.
(*d*) Experimental, applied research.
(*e*) A model flume 180 feet long and 22.7 feet wide is being used to experimentally develop mathematical methods of predicting bridge backwater profiles for various bridge configurations and flood plain roughness conditions. Additionally, analytical approaches to design of spur dikes will be experimentally verified in the flume.

357-08576-370-00

DEVELOPMENT OF HYDRAULIC DESIGN PROCEDURES FOR STRUCTURAL PLATE PIPE AND PIPE-ARCH CULVERTS USING RESISTANCE FACTORS FROM RECENT RESEARCH

(*c*) Paul N. Zelensky.
(*d*) Theoretical, applied, design research.
(*f*) Complete.
(*g*) Tables of geometric and hydraulic factors are presented

for closed conduit shapes commonly found in water conveyance engineering. The tables provide for different degrees of resistance to flow resulting from different materials used in construction. The methods provide solutions for geometrically similar conduits as circular, oval, and square pipes. Solutions for conduits not geometrically similar, as rectangular and pipe-arch, are aslo included. The methods are presented to allow for rapid calculations by slide rule or mechanical calculators. In addition, the tables of hydraulic factors may be used for simplification of computer operations, especially for non-uniform flow problems.

(*h*) **Computation of Uniform and Non-uniform Flow in Prismatic Conduits,** P. N. Zelensky.

357-08577-360-00

ENERGY DISSIPATORS FOR CULVERTS AND HIGHWAY DRAINAGE STRUCTURES

(*c*) J. Sterling Jones.
(*d*) Experimental, applied research.
(*e*) Investigate various schemes of dissipating energy effectively and economically in highway drainage structures to reduce destructive erosion and undermining at the outlets. The objective is to do laboratory testing of the special case of dissipating the energy in the drainage structure proper and, ultimately, to write a manual that will compare the merits and limitations of several of the schemes that have been investigated in recent years.

357-08578-200-00

DEVELOPMENT OF DESIGN PROCEDURES FOR CORRUGATED METAL CONDUITS

(*c*) Paul Zelensky.
(*d*) Theoretical, design.
(*e*) A method of quick computation of approximate backwater profiles in circular corrugated metal pipes is being devised for the following conditions: pipe diameters (D) of 5, 10, and 20 feet; bed slopes (S_o) of 0.000 to 0.014; increments of 0.002; and discharge (Q) of $CD^{5/2}$ for C equal to 1 to 5.

PROJECT REPORTS FROM CANADIAN LABORATORIES

ACRES CONSULTING SERVICES LIMITED, 5259 Dorchester Road, Niagara Falls, Canada. C. H. Atkinson, Head, Hydraulic Department. (See also Acres American Incorporated.)

400-07385-300-87

NAN RIVER HYDRAULIC MODEL

(*b*) Electricity Generating Authority of Thailand (EGAT).
(*d*) Experimental; for design.
(*e*) A hydraulic model to investigate the effects on irrigation and navigation due to the intermittent operation of the proposed Sirikit Power Development in the 300 km reach of the Nan River below the development. The model was constructed at Bangkok, Thailand and built to scales of 1:40 vertically and 1:600 horizontally. Provision was made to extend the model to simulate the next 140 km approximately of the river to beyond the confluence with the Ping River if required. Automatic programming of the river flows was provided and remote sensing of stage heights enabled the resulting hydrographs to be plotted by an oscillograph located in the console in the control building. The test program also included an investigation of the possibility of reducing the effects of intermittent operations by the construction of a regulating after-bay immediately downstream from the powerhouse under construction.
(*f*) Primary testing completed; model active.
(*g*) The model successfully demonstrated that the regulating after-bay smoothed the flows from the Sirikit Power Development as predicted, and that virtually no limitations need be placed on the plant operation.

400-08143-870-75

MODEL STUDIES OF SUBMERGED JET DIFFUSERS

(*b*) Quirk Lawler & Matuski Engineers, 415 Route 303, Tappan, N.Y. 10983.
(*d*) Experimental; design.
(*e*) Proposed additional units to Niagara Mohawk's Oswego Steam Station require additional heat disposal facilities to Lake Ontario. A model study of the effects of such heat input is a mandatory requirement of the New York State Commission for granting a license to construct.
The model study was the first of a two-model program and comprised a 1:20 scale model to determine the close field effects of various underwater jet arrangements. In a basin approximately 24 feet wide and 36 feet long, a row of five jets was arranged so that various prototype diameters from 3 feet to 1 foot 6 inches could be tested in various lateral and vertical angles. A gas-fired boiler rated at 750,000 Btu/hour in conjunction with an insulated storage tank provided the hot water through a specially designed mixing valve. The injected water at a temperature of 28.5 degrees F was the same as the prototype. One hundred and fifty temperature sensors, specially designed and constructed by Acres, were suspended from a horizontal beam at different depths and distances in a vertical plane parallel to the direction of flow. An electronic scanning system sampled the reading of each of the 150 sensors and produced a printout of the values in 15 seconds to 0.01°F. By moving the beam laterally to the direction of flow and repeating the scan, the entire three-dimensional field was recorded.
(*f*) Complete.
(*g*) In the particular application, twinning of the jets along the row with a small horizontal angle between the pairs proved the most economical arrangement that met the requirements. Report submitted to client.

400-08144-870-75

MODEL STUDIES OF THERMAL DISCHARGE INTO LAKE ONTARIO

(*b*) Quirk Lawler and Matuski Engineers, 415, Route 303, Tappan, N.Y. 10983.
(*d*) Experimental; design.
(*e*) Proposed additional units to Niagara Mohawk's Oswego Steam Station require additional heat disposal facilities to Lake Ontario. A model study of the effects of such heat input is a mandatory requirement to New York State Commission for granting a license to construct.
This study was the second of a two-model program and was constructed in a basin approximately 80- by 40-feet, representing approximately 3 miles of the shore-line of Lake Ontario including the wharves and breakwaters of Oswego harbor and extending 1,000 feet out into the lake. The scale was distorted, 1:250 for the horizontal and 1:40 for the vertical scale. Lake drift was simulated by a system of adjustable weirs and openings in a supply manifold situated along the three boundaries of the model which represented the lake. Measured supplies of temperature controlled water simulated the flow of Oswego River and the existing discharges from the generating station. Metered outlets from the model simulated the city water intake and the various intakes for the existing and proposed supplies to the generating station. The model was constructed alongside the first model of the submerged jet diffusers, described above, and used the same boiler and instrumentation facilities.
A row of jets representing the proposed discharge was tested in various locations and 150 temperature sensors were suspended from an overhead framework so that the sensing tips were immersed at the correct depth. By raising or lowering the frames, the temperature fields could be measured at various depths. The time taken to adjust the depth and read the whole field of 150 was approximately 45 seconds. By careful control of the ambient air temperature, the far field isotherms were obtained and, dependent on the direction of lake drift, the combined temperature effects of the station discharge with that from the Oswego River.
(*f*) Completed.
(*g*) A location and orientation of the row of jets was found to effectively meet the requirements of the N.Y. State Dept. of Environmental Conservation, namely, that the isotherm 3° above ambient lake temperature enclosed a surface area less than 6-1/2 acres. Report submitted to client.

400-08145-870-73

THERMAL MODEL FOR BELL NUCLEAR GENERATING STATION

(*b*) N.Y. State Electric and Gas Corp., 4500 Vestal Parkway E., Binghamton, N.Y. 13902.
(*d*) Experimental; design.

(*e*) The site of the proposed Bell Nuclear Power Station is located on the east side of Cayuga Lake in upper New York State. Before allowing lake water to be used for cooling purposes, a model study to demonstrate the adequacy of the dilution and diffusion of the heat outlets is a mandatory requirement of the New York State Department of Environmental Conservation. A proposal to draw water from the hypolimnion of the lake and return it to the epilimnion is being studied by means of a 1:80 natural scale model of some 1-1/4 miles of the east shore of the lake with the below water topography extending about 1/2 mile out into the lake. A system of nozzles has been installed to inject water at the correct temperature at the proposed location together with further outlets to inject the heated water from the Milliken fossil fuel station already existing 0.4 miles south of the proposed nuclear station.

A system of adjustable weirs enables lake drift currents, both northwards and southwards, to be simulated so that effects of the combined heat in-puts by the two stations can be studied. Temperature sensors designed and made by Acres staff are suspended from an overhead framework to enable temperature readings to be taken at one hundred and fifty locations in the model. By raising or lowering the overhead frames, readings can be taken at different depths. Automatic printout of the temperatures of these one hundred and fifty probes is obtained in 15 seconds. The readings are taken to 0.01°F. The whole of the model system is within an insulated room which is maintained at the same temperature as the water (44°F). The study will include the determination of the various isotherms with the object of limiting the area within the isotherm that is 3°above the ambient lake temperature to within that prescribed by the New York State Department of Environmental Conservation.

(*g*) Studies so far have shown that there is interaction of the thermal discharges of the two stations and that the next steps in the study will be towards reducing this interaction.

400-08146-870-70

AIR MODEL STUDIES OF ELECTROSTATIC PRECIPITATORS FOR COFFEEN STEAM STATION, NIAGARA MOHAWK POWER CORPORATION

(*b*) Western Precipitator Division, Joy Manufacturing Company, Los Angeles, Calif.
(*d*) Experimental; design.
(*e*) The insertion of an electrostatic dust precipitator into the flues of an existing thermal power plant generally requires extensive and complicated ductwork. The requirements of minimizing head losses in the ductwork and achieving a uniform flow distribution through the precipitator to maintain a high degree of efficiency require model studies. A model to a scale of 1:16 of the precipitator and its dust collector curtains, hoppers, etc., and associated ductwork was used for the study. The model was manufactured in plexiglass with the exception of the collector curtains which were from steel. The precipitator is 29 feet 8 inches high, 122 feet 4 inches wide and 35 feet long. The study is concerned with the necessity to distribute the gas flow evenly over the collector curtains with the minimum of turbulence and head loss. In the approach ductwork, space restrictions dictate short radius bends so that the placing of guide vanes and diffuser screens constitutes the main part of the test program. The study also includes an investigation of the flow conditions in the ductwork with particular reference to the location of possible areas of dust buildup. An anemometer with automatic traversing and plotting capabilities is employed to ensure uniformity of readings and continuous recording of the velocity profiles.
(*f*) Completed.
(*g*) The tests indicated that certain modifications of the guide vanes and locations of the screens would achieve a sufficiently uniform flow distribution to satisfy the recommended limits of the Industrial Gas Cleaning Institute. Report submitted to client.

400-08147-870-70

AIR MODEL STUDIES OF ELECTROSTATIC PRECIPITATORS FOR HUNTLEY STEAM STATION, UNIT 67, NIAGARA MOHAWK POWER CORPORATION

(*b*) Western Precipitator Division, Joy Manufacturing Company, Los Angeles, Calif.
(*d*) Experimental; design.
(*e*) See (08146).
(*g*) Precipitator 33 feet 8 inches high, 56 feet 10 inches wide, 49 feet 10 inches long.
(*f*) Completed. Report submitted to client.

400-08148-870-70

AIR MODEL STUDIES OF ELECTROSTATIC PRECIPITATORS FOR HUNTLEY STEAM STATION, UNITS 65 AND 66, NIAGARA MOHAWK POWER CORPORATION

(*b*) Western Precipitator Division, Joy Manufacturing Company, Los Angeles, Calif.
(*d*) Experimental; design.
(*e*) See (08146).
(*g*) Precipitator 26 feet 8 inches high, 58 feet 4 inches wide, 31 feet 4 inches long.
(*f*) Completed. Report prepared and submitted to client.

400-08149-870-70

AIR MODEL STUDIES OF ELECTROSTATIC PRECIPITATORS FOR HUNTLEY STEAM STATION, UNITS 63 AND 64, NIAGARA MOHAWK POWER CORPORATION

(*b*) Western Precipitator Division, Joy Manufacturing Company, Los Angeles, Calif.
(*d*) Experimental; design.
(*e*) See (08146).
(*g*) Precipitators 26 feet 8 inches high, 58 feet 4 inches wide, 31 feet 4 inches long.
(*f*) Completed. Report prepared and submitted to client.

400-08150-870-70

AIR MODEL STUDIES OF ELECTROSTATIC PRECIPITATORS FOR DUNKIRK STEAM STATION, UNITS 1 AND 2, NIAGARA MOHAWK POWER CORPORATION

(*b*) Western Precipitator Division, Joy Manufacturing Company, Los Angeles, Calif.
(*d*) Experimental; design.
(*e*) See (08146).
(*g*) Precipitator 49 feet 10 inches long, 56 feet 6 inches wide, 31 feet 8 inches high.

400-08151-870-70

AIR MODEL STUDIES OF ELECTROSTATIC PRECIPITATORS FOR DUNKIRK STEAM STATION, UNITS 3 AND 4, NIAGARA MOHAWK POWER CORPORATION

(*b*) Western Precipitator Division, Joy Manufacturing Company, Los Angeles, Calif.
(*d*) Experimental; design.
(*e*) See (08146).
(*g*) Precipitator 49 feet 10 inches long, 62 feet 6 inches wide, 31 feet 8 inches high.

400-08152-350-87

MODEL TEST OF CONCRETE-LINED TUNNEL FOR THE ALTO ANCHICAYA HYDRO-ELECTRIC PROJECT

(*b*) Corporacion Autonoma Regional del Cauca- CVC, Cali, Colombia.
(*d*) Experimental; design.
(*e*) Geological conditions at the damsite governed the location of the bypass unwatering tunnel resulting in hydraulically undesirable approach conditions at the entrance and a potentially dangerous scour condition at the exit. A model

comprising the approach topography, a plexiglass model of the tunnel including the entrance and exit portals, and a length of river at the exit with an erodible bed extending 100 meters downstream was made to a natural scale of 1:30. The steep sided valley was also modeled in an erodible material up to an elevation of 60 meters above the riverbed. Studies were made to avoid excessive turbulence and air entrainment at the entrance to measure pressure fluctuations at the tunnel walls during transition from free flow to full flow and, of the scour at the near 90-degree emergence angle at the exit. The tests were run to determine the probable stable condition resulting from the continuous erosion of partial slope failure debris.
(*f*) Completed.
(*g*) The test results called for a change in the angles of the approach wing walls at the entrance portal resulting in relatively smooth-surfaced flow conditions for all anticipated flows. The transition from free flow to full flow in the tunnel itself resulted in higher tunnel wall pressures than expected. Scour at the tunnel exit stabilized in a pool 7 meters deep as a result of debris from slope failures of the opposite bank forming a broad crested weir downstream. Report submitted to client.

400-08153-360-73

INSTALLATION OF ENERGY DISSIPATION VALVES ON CANEADEA DAM

(*b*) Rochester Gas and Electric Corporation, 89 East Avenue, Rochester, N.Y.
(*d*) Experimental; design.
(*e*) The existing Johnston regulatory valves on the 40-year old Caneadea Dam were in need of major overhaul. An alternative solution was to install new valves of a higher capacity. A model to a scale of 1:24 was used to determine the location and orientation of two 6-foot diameter Howell-Bunger valves to minimize erosion of the riverbed at the toe of the dam.
(*f*) Completed.
(*g*) Model tests showed that correct orientation of the valves would result in no scour at the toe of the dam. Report submitted to client.

400-08154-870-00

HYDRAULIC MODELING OF CHIMNEY PLUMES

(*d*) Experimental; basic research.
(*e*) A model study was carried out to investigate the feasibility of simulating dispersion and convection in the atmosphere using calcium chloride solutions of various concentrations. By differentially injecting the salt solution, a typical density profile was established in a moving stream of fresh water in a 1-foot square conduit. Tests were also made inducing a vertical velocity gradient similar to the one observed in the atmosphere. Finally, tests were carried out modeling a chimney plume discharging into both neutral (no salt injection) and a stable atmosphere.
(*f*) First stage completed, model inactive.
(*g*) The results obtained indicate it is feasible to simulate density and velocity gradients for both neutral and stable atmospheric conditions, but the technique is sensitive to the design of the apparatus and particularly the salt injection equipment. Interim report prepared.

400-08155-360-00

ASLANTAS PROJECT–PRELIMINARY STILLING BASIN MODEL STUDY

(*d*) Experimental; design.
(*e*) The stilling basin for the Aslantas Project must provide energy dissipation for approximately 12,000 cubic meters per second with a total head difference of 72 meters. Extensive model tests will be required to provide information for detail design. In order to provide some preliminary results to provide basic information for first design an abbreviated study was carried out on a model to a scale 1:100.
(*f*) Completed.
(*g*) The results of the model tests proved to be very closely in accord with predictions based on criteria not originally intended for such high values. Report prepared.

RESEARCH COUNCIL OF ALBERTA, HIGHWAY AND RIVER ENGINEERING DIVISION, 303 Civil Engineering Building, University of Alberta, Edmonton 7, Alberta, Canada. Mr. C. R. Neill, Hydraulic Engineer. (NOTE; The Council participates along with the Department of Civil Engineering, University of Alberta–see below–in a Cooperative Research Program involving also other provincial agencies.)

401-07884-700-90

BED-LOAD MEASUREMENT TECHNIQUES

(*b*) Water Survey of Canada.
(*d*) Experimental; applied research.
(*e*) Reduced-scale study of efficiencies and timewise distributions of catches, using Basket samplers in mixed gravel bed-load.
(*g*) Experimental efficiencies are generally in line with previously-estimated full-scale field efficiencies. Data are available on statistical variability of sampler catches under various transport conditions. Report is in course of preparation.
(*h*) **Sediment Transport Measurements in Gravel River,** A. B. Hollingshead, *J. Hydr. Div. ASCE*, Nov. 1971, p. 1817-1834. (Describes previous field investigations; experimental project is a follow-up.)

401-07885-370-99

GUIDE TO BRIDGE HYDRAULICS

(*b*) Roads and Transportation Association of Canada.
(*d*) Preparation of manual.
(*e*) A cooperative project involving highway organizations throughout Canada. Manual is based on available information and best Canadian practice.
(*f*) Complete.
(*h*) To be published late 1972 by Roads and Transportation Association of Canada, Ottawa.

401-07886-370-96

ICE FORCES ON BRIDGE PIERS

(*b*) Alberta Department of Highways and Transport.
(*d*) Field investigation; applied research.
(*e*) Measurement of dynamic forces during spring break-up on two special piers in different rivers.
(*g*) Measurements over five seasons produced maximum instantaneous unit pressures of up to approximately 300 lb/in^2 (21 kgf/cm^2) on a vertical cylindrical pier. Maximum unit pressures sustained for periods of one second or so were considerably smaller. Maximum instantaneous pressures on a pier inclined at 23° to the vertical were approximately 170 lb/in^2 (12 kgf/cm^2).
(*h*) **Ice Pressure on Bridge Piers in Alberta, Canada,** C. R. Neill, *Proc. IAHR Ice Symp.*, Reykjayik, Paper 6.1., 1970.
Force Fluctuations During Ice-Floe Impact on Piers, C. R. Neill, submitted for *IAHR Ice Symp.*, Leningrad, 1972.

401-07887-220-96

SCOUR DEPTHS IN RIVERS

(*b*) Alberta Dept. of Highways and Transport, Alberta Division of Water Resources.
(*d*) Field and analytical; applied research.
(*e*) Soundings are made in various rivers, especially around bridge foundations, in constrictions, and in sharp bends, under different flow conditions, to determine depth variations and maximum depths of scour, as well as sequences of scour and fill. Attention is given to geological and geotechnical as well as to hydraulic factors.
(*g*) Data have been obtained in a number of rivers over a period of several years, and some analysis has been done.

(*h*) **Report on Bridge Pier Scour Surveys,** A. B. Hollingshead, H. Schultz, limited-distribution progress report, Cooperative Research Program, 1970.
Analysis of Channel Regime, North Saskatchewan River, Edmonton to Provincial Boundary, B. A. Nwachukwu, C. R. Neill, limited-distribution progress report, Cooperative Research Program, 1972.

401-07888-300-96

HYDRAULIC AND GEOMORPHIC CHARACTERISTICS OF RIVERS IN ALBERTA

(*b*) In cooperation with Alberta Div. of Water Resources, and Univ. of Alberta.
(*d*) Field and analytical; applied research.
(*e*) Data have been compiled for approximately 120 short lengths of rivers adjacent to stream gauging stations. Data cover hydraulic geometry, slopes, velocities, heights of flood-plain and benches, channel materials, geological environment, airphoto interpretation, etc.
(*f*) Nearly completed.
(*h*) **Hydraulic and Geomorphic Characteristics of Rivers in Alberta,** R. Kellerhals, C. R. Neill, D. I. Bray. In preparation for publication by Research Council of Alberta.

401-07889-220-96

SEDIMENTATION IN RESERVOIRS

(*b*) In cooperation with Alberta Division of Water Resources.
(*d*) Field, applied research and operations.
(*e*) Measurements are made of sediment accumulation in a number of reservoirs.
(*g*) Considerable sediment accumulation has been found in one or two reservoirs in Southern Alberta. Unit sediment yields have been estimated for a number of basins on the basis of reservoir deposition and river measurements.
(*h*) **Sedimentation in Glenmore Reservoir, Calgary, Alberta,** A. B. Hollingshead, E. K. Yaremko, C. R. Neill. In preparation for submission to Canadian Geotechnical Journal, Ottawa.

401-07890-810-96

SEDIMENT YIELDS FROM MEDIUM-SIZED BASINS

(*b*) In cooperation with Dept. of Geography, Univ. of Alberta, for Alberta Division of Water Resources.
(*c*) Dr. H. J. McPherson, Dept. of Geography, Univ. of Alberta, Edmonton.
(*d*) Field and analytical; applied research.
(*e*) Intermittent sampling for suspended and dissolved solids is done at approximately 50 streamgauging stations during significant runoff events. Attempts will be made to estimate approximate sediment yields on the basis of rating and flow-duration charts. Variations will be analyzed on basis of geographic factors.
(*g*) Not yet available.

UNIVERSITY OF ALBERTA, Department of Chemical and Petroleum Engineering, Edmonton 7, Alberta, Canada.

402-07832-250-90

LAMINAR AND TURBULENT ENTRY FLOW OF POLYMER SOLUTIONS

(*b*) University on NRC Grant.
(*c*) Dr. F. A. Seyer.
(*d*) Experimental, M.Sc. thesis.
(*e*) Experiment measurement of contraction losses and entrance length for flow of drag reducing fluids.
(*h*) **Laminar and Turbulent Entry Flow of Polymer Solutions,** F. A. Seyer, P. J. Catania, *Canad. J.Ch.E.* **50,** 31, 1972.

402-07833-250-90

TURBULENCE STRUCTURE OF DRAG REDUCING FLUIDS

(*b*) NRC Grant.
(*c*) Dr. F. A. Seyer.
(*d*) Experimental and theoretical.
(*e*) Streak photograph techniques are being used to study mechanism of drag reduction.
(*h*) **Turbulence Structure of Drag Reducing Fluids,** A. Rollin, *Ph.D. Thesis,* 1971.

402-07834-070-90

FLOW OF POLYMER SOLUTIONS IN POROUS MEDIA

(*b*) Government Grant.
(*c*) Dr. F. A. Seyer.
(*d*) Experimental and theoretical.
(*e*) Study of flow field in model porous media using streak photograph techniques. Ultimately hope to understand mechanism of enhanced recovery in oil-well flooding operations using polymer solutions.
(*g*) Equipment constructed and data are being collected.

402-07835-370-96

DEVELOPMENT OF CORRELATIVE MODELS IN CAPSULE PIPELINING

(*b*) Research Council of Alberta, as part of a program conducted for the Canadian Transport Development Agency.
(*c*) Professor Donald Quon.
(*d*) Project proposed to analyze the experimental data gathered by the staff of the Research Council of Alberta. It is applied research and will be the basis for a Doctoral thesis.
(*e*) Determine relationships that exist between the physical parameters characterizing flow of capsules in pipelines (with water or oil as the carrier). The main effort is in model-building, primarily on an empirical basis but an attempt will be made to do some theoretical analysis. These models will hopefully form the basis of pipeline design equations as well as throw some light on the physics of capsule flow. Empirical relationships are being developed between capsule velocity and the following variables: liquid velocity, pipe diameter, ratio of capsule to pipe diameter, and ratio of capsule to liquid density. The pressure drop is also being correlated with the same set of variables. As additional data become available, these correlations will be extended.
(*g*) Results are available only in internal reports which are not for general circulation.

UNIVERSITY OF ALBERTA, Department of Civil Engineering, Edmonton 7, Alberta, Canada. Dr. T. Blench, Professor.

403-06630-300-90

ALBERTAN COOPERATIVE STUDIES OF RIVER REGIME

(*b*) University on NRC Grant.
(*d*) Basic and applied research.
(*e*) To aid the development of a formal quantitative inductive science of the self-adjustment of channels that form at least part of their boundaries in sediment. Steps are to collect and assess data; analyze and coordinate them in terms of an adequate "statement of case"; reduce the results to readily intelligible form, usually graphical; publicize the data, the results and their applications; and cooperate with other agencies.
(*g*) Readily available publications contain (i) the principles of statement of case, a method of coordination, and discussion of defects of data with remedies, Refs. 1-3, (ii) a collection of flume data, raw and in numerics, with punch cards, Ref. 8, (iii) a detailed analysis of these data, Ref. 9, (iv) a presentation of results for civil engineering use, Ref. 10, (v) a condensation of results from Indian irrigation canals, Ref. 4, (vi) dimensionless charts for depth and slope to coordinate river, canal and flume data, Ref. 5, (vii) simply graphed data for use of river ecologists, Ref. 6. Ref. 7 became available through membership of a cooperative program; this author records and analyzes

river data obtained as part of a program by the Highway and River Engineering Division of the Research Council of Alberta. To date the impact of dimensionless coordination of data appears comparable with that of the friction factor diagram on early rigid boundary hydraulics, but it requires more independent variables.

(*h*) **Mobile-Bed Fluviology,** T. Blench, 2nd ed., Univ. of Alberta Press, 1969.

Coordination in Mobile-Bed Hydraulics, T. Blench, *J. Hydraul. Div., ASCE* **95,** HY6, Proc. Paper 6884, Nov. 1969, pp. 1871-1898. Closure in **97,** HY2, Proc. Paper 1364, Feb. 1971.

Mobile Bed Hydraulics, T. Blench, *J. Hydraul. Res.* **8,** 2, 1970.

Regime Theory Design of Canals with Sand Beds, T. Blench, *J. Irrig. and Drainage Div., ASCE* **96,** IR2, Proc. Paper 7381, June 1970, pp. 205-213.

Discussion of **Sediment Transportation Mechanics, F. Hydraulic Relations for Alluvial Streams,** T. Blench, *J. Hydraul. Div., ASCE* **97,** HY11, Proc. Paper 8483, Nov. 1971, pp. 1908-1913.

Morphometric Changes, T. Blench, *Proc. Intl. Symp. on River Ecology and Impact of Man*, June 1971. Available Dept. of Natural Resources, Cornell Univ., Ithaca, N.Y.

Generalised Regime Type Analysis of Alberta Rivers, D. I. Bray, *Ph.D. Thesis*, Univ. of Alberta, 1972.

A Review of Data from Sediment Transport Experiments, R. H. Cooper, A. W. Peterson, *Rept. No. HY-1969-ST2*, Dept. of Civil Engrg., Univ. of Alberta and U.S. Dept. of Commerce, *NTIS No. PB-190233*, 1970.

A Study of Bed Material Transport Based on the Analysis of Flume Experiments, R. H. Cooper, *Ph.D. Thesis*, Univ. of Alberta, 1970.

A Critical Review of Sediment Transport Experiments, R. H. Cooper, A. W. Peterson, T. Blench, *J. Hydraul. Div., ASCE* **98,** HY5.

403-07836-220-00

FLOW IN ALLUVIAL CHANNELS

(*c*) A. W. Peterson, Assoc. Professor.
(*d*) Experimental studies of sediment transport in open channels and analysis of world data.
(*e*) The behavior of flow in alluvial channels is being studied by analyzing the majority of the available experimental flume data.
(*g*) Graphical relationships have been developed for predicting flow variables. See scope of Experimental and Practical Conditions for Flow in Mobile Bed Channel, ASCE Natl. Water Resources Engrg. Mtg., Phoenix, Ariz., Jan. 1971.

403-07837-050-90

TURBULENT COMPOUND ANNULAR SHEAR LAYERS

(*b*) University on NRC Grant.
(*c*) Dr. N. Rajaratnam.
(*d*) Basic problem, theoretical and experimental.
(*e*) Similarity analysis of the Reynolds equations, with some experiments conducted mainly to support the analysis and to evaluate the empirical constants involved in the analysis.
(*f*) Completed.
(*g*) It was found theoretically and experimentally that the length characteristics of this type of shear layer vary linearly with the axial distance. The characteristic empirical coefficient c^2 was found to vary appreciably with the ratio of the primary jet velocity to the velocity of the secondary stream. Further the variation of the length of the potential core with this velocity ratio was also evaluated.
(*h*) **Turbulent Compound Annular Shear Layers,** N. Rajaratnam, B. S. Pani, *Proc. ASCE, J. Hydraul. Div.*, 1972.

403-07838-050-90

THREE-DIMENSIONAL TURBULENT WALL JETS

(*b*) University on NRC Grant.
(*c*) Dr. N. Rajaratnam.
(*d*) Basic problem with practical applications; theoretical and experimental.
(*e*) Develop a general method of predicting the characteristics of three-dimensional turbulent wall jets and also to compute the flow below submerged hydraulic outlets.
(*g*) Using some basic experimental results, a similarity analysis has been successfully performed on the relevant Reynolds equations. Dimensional considerations indicated a very useful length scale. Experimental results from a number of outlet shapes have been used to consolidate the theoretical predictions. It has also been found that a certain amount of swirl given to a circular wall jet helps very much in the energy dissipation.
(*h*) **Three-Dimensional Turbulent Wall Jets,** B. S. Pani, *Ph.D. Thesis*, June 1972.

403-07839-050-90

PLANE TURBULENT COMPOUND WALL JETS

(*b*) University on NRC Grant.
(*c*) Dr. N. Rajaratnam.
(*d*) Analytical.
(*e*) Develop a method of computation of plane compound wall jets.
(*f*) Completed.
(*g*) Using the similarity analysis of the Reynolds equations and the integral momentum equation, dimensional analysis and the available experimental data, a simple method has been developed to predict the variation of the velocity and length scales and the wall shear stress for the plane wall jet with a free stream of constant velocity.
(*h*) **Plane Turbulent Compound Wall Jets,** N. Rajaratnam, *J. of Hydraul. Res.*, 1972.

403-07840-700-90

STUDIES ON PRESTON TUBE

(*b*) University for Dept. of Energy, Mines & Resources, Ottawa, Ontario.
(*c*) Dr. N. Rajaratnam.
(*d*) Experimental.
(*e*) Develop a calibration chart for Preston tube on smooth and rough walls.
(*g*) Based on many careful experiments, a calibration chart has been developed for Preston tubes for use in smooth turbulent flow, rough turbulent flow and also in the transition region in between. Further work is in progress to extend this technique to shear measurement over non-uniformly rough surfaces.
(*h*) **A Calibration Chart for Preston Tubes,** A. B. Hollingshead, N. Rajaratnam. Under publication.

403-07841-200-90

BOUNDARY SHEAR STRESS DISTRIBUTION IN OPEN CHANNELS

(*b*) University for Dept. of Energy, Mines and Resources, Ottawa, Ontario.
(*c*) Dr. N. Rajaratnam.
(*d*) Analytical and experimental.
(*e*) Measure the shear stress distribution for a variety of channel shapes and to rationalize turbulent flow in open channels.
(*g*) Very extensive measurements have been made regarding the distribution of velocity and boundary shear in smooth and rough rectangular and trapezoidal channels. A number of roughnesses have been studied. Keulegan's velocity distribution equations have been compared with experimental results. A number of interesting and useful results have been obtained.

(*h*) **An Experimental Study of Turbulent Flow in Rough Rectangular Open Channels**, N. Rajaratnam, *Tech. Rept.*, 1970.
An Experimental Study of Turbulent Flow in Smooth and Rough Trapezoidal Channels, N. Rajaratnam, D. Muralidhar, *Tech. Rept.*, 1970.
Boundary Shear Stress Distribution in Open Channels, A. B. Hollingshead, *Ph.D. Thesis*, 1972.

403-07842-360-90

FORCED HYDRAULIC JUMPS

(*b*) University on NRC Grants.
(*c*) Dr. N. Rajaratnam.
(*d*) Analytical and experimental.
(*e*) To predict the forces on baffle walls and blocks.
(*f*) Completed.
(*g*) The pressure distribution on baffle walls and blocks was experimentally obtained and the drag forces were computed. Further the mean velocity distribution in the forced jump was measured and correlated using the plane wall jet as the flow model.
(*h*) **A Contribution to Forced Hydraulic Jumps**, N. Rajaratnam, V. Murahari, *J. Hydraul. Res.*, 1971.

403-07843-360-90

JUMPS IN SLOPING CHANNELS

(*b*) University on NRC Grant.
(*c*) Dr. N. Rajaratnam.
(*d*) Analytical and experimental.
(*e*) To study the mean flow characteristics of the sloping channel jump.
(*f*) Completed.
(*g*) A similarity analysis was made on the sloping channel jump treating it as a plane wall jet. Experimental observations made on jumps on slopes of up to 25 percent supported the analysis.
(*h*) **Mean Flow Characteristics of Sloping Channel Jumps**, N. Rajaratnam, V. Murahari. Under publication.

403-07844-030-90

WALL WAKES

(*b*) University on NRC Grant.
(*c*) Dr. N. Rajaratnam.
(*d*) Analytical and experimental.
(*e*) To study the nature of wakes which are constrained by the presence of walls.
(*g*) Plane turbulent wall wakes with and without pressure gradients are being studied experimentally in a wind tunnel. Further studies will cover three-dimensional wall wakes also.

403-07845-050-90

IMPINGING JETS

(*b*) University on NRC Grant.
(*c*) Dr. N. Rajaratnam.
(*d*) Analytical and experimental.
(*e*) To study the flow characteristics.
(*g*) Using some basic experimental results and the equations of motion, a method has been developed to predict the characteristics of plane impinging jets in the three regions of flow. The impinging region has been studied extensively.
(*h*) **Plane Turbulent Impinging Jets on Smooth Walls**, S. Beltaos, *M.Sc. Thesis*, 1972.

403-07846-050-90

TURBULENT JETS IN CROSS FLOW

(*b*) University on NRC Grant.
(*c*) Dr. N. Rajaratnam.
(*d*) Analytical and experimental.
(*e*) Develop a method of predicting the characteristics of jets in cross flow.
(*g*) The equations of motion for a general curved jet are under study. Experimental study is also in progress.

403-07847-390-90

HYDRAULICS OF END-DUMP TYPE RIVER CLOSURE

(*b*) University on NRC Grant.
(*c*) J. B. Nuttall.
(*d*) Applied research, experimental, Doctoral thesis.
(*e*) Investigate the hydraulic performance, material size and quantity required in end-dump river closures.
(*g*) Design graphs relating the various non-dimensional parameters have been prepared. Good correlation with the few full scale tests reported in the literature has been demonstrated. Thesis and paper in preparation.

403-07848-300-90

SURGES IN ICE COVERED CHANNELS

(*b*) University on NRC Grant.
(*c*) J. B. Nuttall.
(*d*) Applied research, analytical.
(*e*) To investigate the effect of an ice cover on open channel surges and to compare the results of numerical calculations to observations on a river.
(*g*) Friction losses determined from steady flow under ice were used in conjunction with standard numerical procedures for open channel surges. The assumption that ice affects the result only through the friction term was verified by comparison with stage records made on a reach of the North-Saskatchewan River downstream from a hydro plant.
(*h*) **Surges in Ice Covered Channels**, D. M. Liland, *Master's Thesis*, Univ. of Alberta, 1971.

403-07849-810-90

ARCTIC LAND USE RESEARCH

(*b*) Dept. of Indian Affairs and Northern Development (DIAND).
(*c*) Dr. J. P. Verschuren.
(*d*) Field and theoretical investigation; applied research.
(*e*) Determination of the effects of land use changes on the hydrologic regime in the Boreal forests of the Yukon. As part of the investigation a classification of the hydrologic, geomorphologic and climatologic regime is underway for the entire Yukon and Mackenzie drainage basins. Break-up, and freeze-up phenomena, and the thickness of ice in the major rivers are considered. Extensive use is made of fluorescent tracer.
(*h*) 1970 and 1971 Progress Reports are available from DIAND, Ottawa, Canada.

403-07850-810-90

DESIGN FLOW HYDROGRAPHS

(*b*) National Research Council, Ottawa, Canada.
(*c*) Dr. J. P. Verschuren.
(*d*) Theoretical; Master's thesis.
(*e*) Determination of the shape of the design hydrographs based on the statistical distribution of the rate of increase and rate of decrease of discharge for three stations on the North-Saskatchewan River in Alberta.
(*f*) Completed.
(*g*) The combination of the median recession curve and the rising curve with probability equal to the probability of occurrence of the flood peak simulate the actual measured hydrograph. A record length of 13 years was found to provide sufficient data to simulate the flood hydrograph. The method can be used to derive the flood hydrograph when the volume of excess precipitation is given.
(*h*) *M.Sc. Thesis*, Dept. of Civil Engrg., Univ. of Alberta.

403-07851-810-90

CLASSIFICATION OF PRECIPITATION

(*b*) Dept. of Energy, Mines and Resources, Ottawa, Canada.
(*c*) Dr. J. P. Verschuren.

517-020 O-LT - 74 - 16

(*d*) Theoretical, applied research, Master's thesis.
(*e*) Determination of two characteristic curves for 13 precipitation stations in Alberta. The curves show the seasonal variation of the two parameters necessary to compute the distribution function of variables such as the amount of rain during a certain time interval, the number of rainy days during a certain time interval, the time required for a specific amount of rain to have occurred.
(*f*) Completed.
(*g*) Results are provided in a series of graphs showing the characteristic curves, and the effects of topography and storm patterns on the characteristic curves. The observational techniques at the weather station effect the curves. About 15 years of record are required to compute reliable curves.
(*h*) *M.Sc. Thesis*, Dept. of Civil Engrg., Univ. of Alberta.

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ATOMIC ENERGY OF CANADA LIMITED, CHALK RIVER NUCLEAR LABORATORIES, Advance Engineering Branch, Chalk River, Ontario, Canada. H. Smedley, Branch Head.

404-07859-130-00

FLUID-TO-FLUID MODELING OF CRITICAL HEAT FLUX AND PRESSURE DROP IN TWO-PHASE FLOW

(*c*) Dr. S. Y. Ahmad.
(*d*) Experimental and theoretical applied research study.
(*e*) Modeling is of practical importance in reducing the high cost of critical heat flux testing for boiling water power reactors. The working fluid water is replaced by a modeling fluid (e.g., Freon) having lower latent heat of vaporization. This reduces the test section power considerably. A generalized technique for such fluid modeling is developed from classical dimensional analysis and theory of models. Experiments complementing the analytical effort have been performed in different geometries for a large range of system parameters.
(*f*) Further tests using rod bundle geometries are in progress. Construction of a Freon loop sufficiently large to simulate conditions in any fuel channel presently envisaged for Canadian power reactor programs, is near completion.
(*g*) The results of theoretical and experimental study have shown that the generalized modeling technique is applicable to various Freon compounds, water, potassium and carbon dioxide. Excellent agreement is shown between experimental data and the critical heat flux modeling technique for circular, annular, and rod bundle geometries. A technique for modeling two-phase pressure drop is currently being tested with experimental data.
(*h*) **Fluid-to-Fluid Modeling of Critical Heat Flux: A Compensated Distortion Model,** S. Y. Ahmad, *Atomic Energy of Canada Ltd. Report No. AECL-3663*, 1971.

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BEDFORD INSTITUTE, Atlantic Oceanographic Laboratory, Marine Sciences Branch, Dartmouth, Nova Scotia, Canada. Director.

405-07852-450-00

AIR SEA INTERACTION

(*c*) S. D. Smith, Air-Sea Interaction Group.
(*d*) Basic research, field investigation.
(*e*) Wind stress on sea surface and on sea ice. Wave generation mechanisms, pressure fluctuations on sea surface.
(*h*) **Wind Stress Over Ice and Over Water in the Beaufort Sea,** E. G. Banke and S. D. Smith, *J. Geophys. Res.* **76**, 30, 7368-7374, 1971.
Measurements of Atmospheric Pressure on Wind-Generated Sea Waves, F. W. Dobson, *J. Fluid Mech.* **48,** 1, 91-127, 1971.

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THE UNIVERSITY OF CALGARY, Department of Mechanical Engineering, Calgary 44, Alberta, Canada. G. A. Karim, Acting Department Head.

406-07319-740-90

NUMERICAL SOLUTION OF FLOW FIELDS

(*b*) National Research Council.
(*c*) Dr. G. de Vries.
(*d*) Theoretical; basic research.
(*e*) Develop finite element methods for the solution of potential as well as more general flow fields, with irregular and multiple boundaries and simple or mixed boundary conditions. The two-dimensional potential flow solution has been obtained. Navier-Stokes, visco-plastic, and compressible flows are under investigation. Further variational and non-variational approaches are envisaged.
(*g*) For two-dimensional potential flow, the finite element method has given good agreement with known solutions. Results have been obtained for compressible and visco-plastic flows.
(*h*) **The Application of the Finite Element Technique to Potential Flow Problems,** G. de Vries, D. H. Norrie, *J. Appl. Mech., Paper No. 71-APM-22*, Dec. 1971, pp. 798-802.
Application of Finite Element Methods in Fluid Dynamics, D. H. Norrie, G. de Vries, to be published by *AGARD*, 1972.
The Application of the Finite Element Method to Unsteady Flow Problems, D. H. Norrie, G. de Vries, *Proc. N.R.C. Seminar on Blade Vibration*, Ottawa, Sept. 11, 1970.
Finite Element Applications, D. H. Norrie, G. de Vries, Academic Press Inc., 1972/73.

406-07320-550-90

PRESSURE FLUCTUATIONS OF AXIAL FLOW MACHINES

(*b*) National Research Council and Defence Research Board Grants.
(*c*) Dr. D. H. Norrie.
(*d*) Theoretical and experimental; basic and applied research.
(*e*) Determine the unsteady potential flow field within an axial-flow machine. The analytic solution for the unsteady field is based upon the Biot-Savart superimposition of unsteady fields using the vortex model put forward by Ordway. The solution for the higher harmonics which was partly presented by this author, using a matrix inversion approach, has been completed. Original alternative solutions based on Gauss-Legendre quadrature and on Chebychev functions have been developed, which reduce greatly the calculation necessary. The associated computer programmes are nearing completion. The higher-harmonic analytic solution is being applied to a previously designed ducted impeller system, and the theoretical calculations will be compared with experimental pressure data already obtained.
(*g*) Calculation of Legendre functions of half-order, and various derived functions, are complete. Results of pressure fluctuations are anticipated in late 1972.
(*h*) **The Fluctuating Pressure Field of a Ducted Propeller,** D. H. Norrie, M. R. Hale, *Symp. on Pumping Machinery for Marine Propulsion, ASME Fluids Engrg. Conf.*, Philadelphia, Pa., May 1968.
Numerical Solution of Integral Equations with Kernels with Weak Singularities, Q. D. Dang, *Mech. Engrg. Dept. Rept. No. 33*, The Univ. of Calgary, May 1971.
A Perturbation Method for the Solution of Singular Integral Equations, Q. D. Dang, *Mech. Engrg. Dept. Rept. No. 36*, The Univ. of Calgary (in preparation).

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CANADA CENTRE FOR INLAND WATERS, Hydraulics Laboratory, P.O. Box 5050, Burlington, Ontario, Canada. T. M. Dick, Head, Hydraulics Unit.

407-07853-700-90

MEASUREMENT OF BED LOAD

(*b*) Cooperative with Sediment Survey Section, Water Survey of Canada, Dept. of the Environment.
(*c*) C. K. Jonys, Research Engineer.
(*d*) Experimental laboratory and field investigation; applied research.
(*e*) Improve bed load measurement technology. Direct bed load sampling and indirect measurements are to be investigated. Measurement error sources using available instruments are to be identified. Simultaneous measurement of various flow parameters in the vicinity of samplers and the interpretation of this information in relation to material accumulation in samplers is to be evaluated. Indirect bed load measurement using hydrophone techniques is to be explored.
(*f*) Project in planning stage.

407-07854-870-00

DIFFUSION OF HEATED EFFLUENTS

(*c*) Dr. Y. L. Lau.
(*d*) Experimental, theoretical; applied research.
(*e*) The project is aimed at predicting the temperature distribution resulting from the discharge of heating effluents into flowing waters. Diffusion and entrainment characteristics of heated jets under different discharge configurations are to be studied.
(*g*) Far-field temperature distributions resulting from heated discharges into open-channel flow have been investigated. Research needed for near-field distributions has been identified.
(*h*) **Temperature Distribution Due to the Release of Heated Effluents Into Channel Flow,** Y. L. Lau, *Tech. Bull. 55*, Inland Waters Branch, Dept. of the Environment, Ottawa, Canada, 1971.

407-07855-200-00

REAERATION IN OPEN-CHANNEL FLOW

(*c*) Dr. Y. L. Lau.
(*d*) Experimental, theoretical; applied research.
(*e*) Investigate the mechanism of atmospheric reaeration in order to obtain more accurate predictions of the reaeration rate and means of improving the oxygen content through manipulation of the hydraulic variables.
(*g*) A state-of-the-art review of the mechanism of absorption and prediction equations has been made. Experiments are being planned.
(*h*) **A Review of Conceptual Models and Prediction Equations for Reaeration in Open-Channel Flow,** Y. L. Lau, *Tech. Bull.*, Inland Waters Branch, Dept. of the Environment, Ottawa, Canada.

407-07856-060-00

PRELIMINARY SURVEY OF FLOW REGIMES IN BURLINGTON CANAL

(*d*) Field investigation, applied research.
(*e*) Two flow regimes have been observed in Burlington Canal which connects a bay to Lake Ontario–gravity flow due to the variation of lake water level, and thermal wedge. The results will help to estimate the mass exchanged between the lake and bay.
(*g*) Fair agreement between field data on the thermal wedge and a two-layered system theory has been found for small densimetric Froude numbers.
(*h*) **Thermal Wedge in an Inlet into Lake Ontario,** T. M. Dick, J. Marsalek, *15th Conf. on Great Lakes Research*, Madison, Wisc., April 1972.

407-07857-870-00

COMBINED SEWER OVERFLOWS

(*c*) J. Marsalek.
(*d*) Experimental; development.
(*e*) Possible contributions of hydraulic engineering to the abatement of combined sewer overflows have been sought. Future study will be aimed at investigation of overflow regulators and separators of solids from a liquid.
(*g*) A literature study of abatement of combined sewer overflows has been completed and needs for further research identified.
(*h*) **Combined Sewer Overflows,** J. Marsalek, *Tech. Bull.*, Inland Waters Branch, Dept. of the Environment, Ottawa, Canada.

407-07858-420-00

TRANSFORMATION OF WAVES IN THE NEARSHORE ZONE

(*c*) J. Marsalek.
(*d*) Field investigation, applied research.
(*e*) To correlate deep water wave data and the nearshore wave data which is required for engineering purposes.

ECOLE POLYTECHNIQUE, Hydraulics Division, Hydrodynamics Laboratory, 2500 Marie-Guyard Avenue, Montreal 250, P.Q., Canada. Professor André Leclerc, Director, Hydrodynamics Laboratory.

408-06823-050-90

TWO-DIMENSIONAL JET IN A STREAMING FLOW

(*b*) National Research Council.
(*c*) Luc Robillard, Assoc. Professor.
(*d*) Experimental and theoretical investigation.
(*e*) Experiments have been performed concerning the jet oscillation and vortex shedding that occur when particular experimental conditions are fulfilled. Other experiments are planned to study penetration of a circular jet in a still fluid, and wall jet in a counter flow.
(*g*) Experimental results indicate that the vortex mechanism is controlled mainly by the interaction of the jet nappe and the uniform flow at high injection velocities.
(*h*) **Mouvement périodique d'un jet bidimensionnel plan dans un contre-courant et production de tourbillons alternés,** Luc Robillard, *J. Mécanique* **10**, 1, Mars 1971.

408-06909-210-90

WATERHAMMER ANALYSIS IN PLASTIC PIPES

(*b*) National Research Council of Canada.
(*c*) Alexandre Godin, Assoc. Professor.
(*d*) Experimental; basic research.
(*e*) Determination of maximum rise and minimum drop in head in a plastic pipe by sudden or progressive closure of a valve. Tests will be performed on different types and sizes of plastic pipes. Evaluation of the pressure wave celerity and determination of the pipe deformation.
(*f*) Tests completed at 95 percent. Evaluation of results and preparation of report active.
(*g*) Water temperature has proved to have a great influence on intensity of pressure wave, damping time and rate of deformation of the pipe. Report under preparation.

408-06913-010-96

LAMINAR BOUNDARY LAYER ALONG A MOVING FLAT BELT

(*b*) Quebec Government.
(*c*) Luc Robillard, Assoc. Professor.
(*d*) Theoretical investigation.
(*e*) This research project was undertaken for a better understanding of the establishment of velocity profiles in turbulent Couette-Poiseuille flow experimentations.

(f) Completed.
(g) A generalized Blasius series has been established. The method of steepest descent has been used to evaluate the constant of integration from the boundary condition at infinity.
(h) **On a Series Solution for the Laminar Boundary Layer Along a Moving Wall,** Luc Robillard, *Trans. ASME, J. Appl. Mech.*, June 1971.

408-08044-220-96

HYDRAULIC EROSION TESTS ON CLAY

(b) Quebec Hydro-Electric Commission.
(c) Alexandre Godin, Assoc. Professor.
(d) Experimental; applied research.
(e) Determination of the critical velocity at which erosion of samples of clay would occur. Tests have been conducted in an 18-in. wide horizontal bottom flume.
(f) Completed.
(g) The critical velocity has been evaluated for different samples. A design value for an open channel dug in this type of clay has been determined.
(h) **Essais d'érosion sur des échantillons d'argile provenant du site Rupert 1,** André Leclerc, Alexandre Godin. Final report submitted to Quebec-Hydro, Mar. 1971.

408-08045-350-96

MODEL STUDY OF LANIEL SPILLWAY

(b) Quebec Hydro-Electric Commission.
(d) Experimental; applied research.
(e) A model has been built to a scale of 1:50 to determine the maximum flow capacity of the spillway. It was also required to determine the best operating conditions of four gates which could be partially or completely, symmetrically or asymmetrically opened.
(f) Completed.
(g) Flow capacity measured on the scale model showed good agreement with the design value. A set of curves has been drawn allowing prediction of rate of flow and location of hydraulic jump under different heads and gates openings.
(h) **Etude sur modèle réduit de l'évacuateur de crues Laniel (Kipawa, Témiscamingue).** Final report submitted to Quebec-Hydro by the Hydraulics Division, Dec. 1971.

LASALLE HYDRAULIC LABORATORY LTD., 0250 St. Patrick Street, LaSalle, P.Q., Canada. R. Hausser, Vice President.

410-06239-300-90

ICE TESTS ON THE ST. LAWRENCE RIVER MODEL

(b) Ministry of Transport, Canada.
(d) Theoretical and experimental; design.
(e) Ice tests have been carried out on 1/150 vertically and 1/500 horizontally scale model of the St. Lawrence in order to study the ice conditions and the solutions to improve them with regard to flood risks and navigation during winter.
(f) Completed.

410-06917-350-96

MANICOUAGAN 3–DIVERSION WORKS

(b) Hydro-Quebec.
(d) Experimental; design.
(e) Study on a 1/100 movable bed scale model of the different phases of construction and utilization of the diversion works. Simulation of ice and timber passage through the diversion tunnel showed the need of control structures including boom and regulating gates at the entrance of the diversion tunnel.
(f) Completed.

410-06931-520-00

BUBBLER ACTION ON FLOATING BODY

(d) Model investigation.
(e) Research on the possibilities of moving floating bodies by adequate use of air bubble curtains. Applications to locks, docks, turning basins, etc., in view to assist vessels.

410-07860-340-73

INDIAN POINT NUCLEAR POWER STATION–UNIT 2–RECIRCULATION IN SCREENWELL

(b) Consolidated Edison Company of New York.
(d) Experimental, for design.
(e) Pumps in the cooling water circuit were originally designed with their optimum operation at a given maximum discharge required by the condensers. When the condensers used less than this discharge, valves reduced the flow, resulting in pump vibrations beyond certain degrees of throttling. A recirculating system was desired that would allow running the pump continuously at its optimum, with the excess flow between this and the condenser requirement being returned to the screenwell. A 1/12 scale model was used to develop a flow dispersion arrangement that would introduce these recirculated discharges to the screenwell without disturbing flow to the bellmouth. The arrangement devised also reduced the velocity through the outer fine screen, thereby cutting down the fish attraction.
(f) Completed.

410-07861-870-36

FUNDAMENTAL RESEARCH ON SWIRL CONCENTRATOR FOR COMBINED SEWER REGULATION

(b) American Public Works Association as the managing agent for the City of Lancaster, Pa., on a research grant from the Environmental Protection Agency.
(d) Basic research.
(e) The concentrator is proposed to be placed as regulator gate in combined sewer systems, where its object is to separate as much as possible of the solid pollutants, and to direct these to the treatment plant. In this manner, the clear overflow can be discharged into the natural water course with a much lower pollution potential. A 1/12 scale model was used to develop the basic geometry of a practical cylindrical chamber with a high solids recovery efficiency.
(f) Stage 1 testing completed; detailed studies continuing.
(g) The chamber so far developed shows distinct promise, so further studies are being considerd to define particular limits for different grain sizes and specific gravities of solid pollutants.

410-07862-340-96

MICA CREEK HYDROELECTRIC PROJECT

(b) British Columbia Hydro and Power Authority, through International Power and Engineering Consultants.
(d) Experimental; design.
(e) 1/84 scale model of the tailrace tunnels, downstream riverbed, spillway and high level outlets. Study of tunnel and manifold headlosses as a function of tunnel level settings and alterable tailwater levels by future construction of another project downstream. Definition of surge levels in the tunnels and manifolds caused by transient turbine operations.
(g) Early phases of work have already introduced significant changes resulting in large scale savings in construction costs. Further basic geometry tests still to do, then concentration on detailed operations to define optimum procedures.

410-07863-210-99

VALCOURT AQUEDUCT

(b) Normandin Construction Ltd.

(*d*) Theoretical; for operation.
(*e*) Investigation of the possible causes of the frequent pipe burstings of the aqueduct has been made. Too rapid discharge of trapped air is suspected to be the main reason for the pipe's bursting, and throttling of the air relief valve was recommended.
(*f*) Completed.

410-07864-330-90

CAP À LA ROCHE–NAVIGATION STUDY

(*b*) Ministry of Transport, Canada.
(*d*) Experimental; design.
(*e*) Study on a 1/150 vertical and 1/500 horizontal scale model of remedial works to improve the difficult navigation conditions existing in the section of Cap à la Roche of the St. Lawrence River.
(*f*) Completed.

410-07865-350-99

MANICOUAGAN 3–WATER INTAKE AND SPILLWAY

(*b*) Asselin Benoit Boucher Ducharme Lapoint Consulting Engineers.
(*d*) Experimental; design and operation.
(*e*) A 1/84 scale model including the turbine intakes, the spillway, the stilling basin and a portion of the movable river bed was built. Tests were made to optimize the rock excavation in front of the intakes, and to finalize the geometry of the stilling basin. This last investigation was guided by the necessity to reduce the erosion hazard and to minimize splashing on the erodable banks of the stilling basin.
(*f*) Completed.

410-07866-400-90

MINI-MODEL OF THE ST. LAWRENCE ESTUARY

(*b*) Ministry of Transport, Canada.
(*d*) Experimental; design.
(*e*) A tidal and movable bed model reproducing 180 miles of the St. Lawrence river from Lake St. Peter to Ile aux coudres has been built with very small scales: 1/10,000 × 1/500. Designed as a pilot model to assist the engineering studies regarding the deepening of the ship channel along Orleans island, it has already given not only qualitative but also valuable quantitative information on sediment movement.

410-07867-870-90

OIL SPILLS

(*b*) Ministry of Transport, Canada.
(*d*) Theoretical and experimental; for operation.
(*e*) An existing 1/600 × 1/150 scale model reproducing forty miles of the St. Lawrence River from Laprairie Basin to Lanoraie is being used to study solutions to limit downstream pollution in case of an accidental oil spill along the Montreal East quays.

410-07868-690-70

WEYERHAEUSER PAPER MILL

(*b*) Badcook–Wilcox Pump Co., Galt, Ontario.
(*d*) Experimental; design.
(*e*) A 1/6 scale model of the silo and the inlet of the fan pump was built to design a suitable pulp injection arrangement in order to achieve acceptable mixing at the inlet of the pump.
(*f*) Completed.

410-07869-870-96

SEWAGE DISPOSAL AT VICTORIA AUTOPARK, MONTREAL

(*b*) Quebec Water Board, Quebec.
(*d*) Model investigation.
(*e*) The existing 1:150 × 1:600 scale model of the St. Lawrence River was used, with the permission of Ministry of Transport (Ottawa), to determine the most appropriate point of disposal of sewage from the proposed treatment plant at Victoria Autopark, and the dispersive characteristics of the effluent all along the river down to Lanoraie (approx. 40 miles downstream from the treatment plant), where complete dilution is achieved.
(*f*) Completed.

410-07870-330-75

DOCKING FACILITIES AT BECANCOUR, QUEBEC

(*b*) Central Quebec Industrial Park Corp., and "Letendre, Monti, Lavoie, Nadon & Jacques Déry," Consulting Engrs., Montreal.
(*d*) Model investigation; design.
(*e*) The proposed docking facilities will extend 4600 ft. from shore into water with a depth of 30 ft. (referred to datum of navigation charts). A 1:600 × 1:150 scale model reproducing 11 miles of the St. Lawrence River was built to assess effects of the proposed structure upon the water levels and the flow distribution in the river, the surface currents in the navigation channel and in the vicinity of the Gentilly Nuclear Power Station, and the most appropriate location of the future effluents. Flow conditions (flow separation and wakes) at the dock itself were also investigated.
(*f*) Completed.

410-07871-340-75

ROSETON GENERATING STATION

(*b*) Burns and Roe, Inc., Consulting Engrs., Oradell, N.J.
(*d*) Model investigation; design.
(*e*) Complementary tests on the existing 1:30 model of the intake structure to study the hydraulic functioning of openings which would be provided in the walls between the pump bays behind the traveling screens. Normally closed by stop-logs, these openings will be used under certain conditions of operation to reduce net screen velocities.
(*f*) Completed.

410-07872-390-75

WATER INTAKE OF "LA COOPERATIVE LAITIERE DU SUD DU QUEBEC, STE CLAIRE, QUEBEC"

(*b*) "La Coopérative Laitière du Sud du Québec," Labrecque, Vézina and Associates, Consulting Engineers.
(*d*) Consulting services.
(*e*) Preliminary study of a new water intake designed to function under severe adverse conditions of ice, frazil, sediment transport and dead leaves at fall.
(*f*) Completed.

410-07873-470-90

HALIFAX CONTAINER TERMINAL

(*b*) Dept. of Public Works of Canada, Ottawa, Ontario; HALICON (Halifax International Containers Limited), Halifax, Nova Scotia.
(*d*) Model investigation.
(*e*) Model tests at scale 1:50 to determine the ship-motions and protective measures required to alleviate the motions to within acceptable limits at the Halifax Container Terminal (alongside Pier C).
(*f*) Completed.

410-07874-410-70

COASTLINE PROTECTION, LAKE ST. JOHN, QUEBEC

(*b*) ALCAN, Power Operations, Quebec.
(*d*) Analytical and field investigation.
(*e*) Appraisal report on the results of the beach replenishing programme under way since 1966 (covering now 98,000 feet of coastline, with quantities of sand dredged offshore

and pumped on the beach exceeding one and a half million of cubic yards). Comparisons between the sites are done, by considering beach profiles year after year, and the hydrographic conditions (there are sites where pure wave action is operative, as opposed to sites with combined wave action and river erosion). Water level fluctuations were also considered as an important parameter and other parameters like the grain-size of the pumped sand.
(*f*) Completed.

410-07875-870-90

SELF-TREATMENT IN SEWERS

(*b*) National Advisory Committee on Water Resources Research; Dept. of Energy, Mines and Resources, Ottawa, Canada.
(*d*) Literature and information search.
(*e*) Establishment of the "state-of-the-art" knowledge of self-treatment in sewers; critical evaluation of the information gathered; recommendations for further research or investigations and sites of applications of the principle.
(*f*) Completed.

410-07876-330-99

UPPER BEAUHARNOIS LOCK APPROACH WALLS

(*b*) The St. Lawrence Seaway Authority, Montreal.
(*d*) Experimental and design.
(*e*) Investigation of the behaviour of 730 ft. vessels during approach manoeuvres and berthing operations to a wall under hazardous lateral currents. Tests carried out in a model built at a scale of 1/60 with a self-propelled, radio controlled ship.
(*f*) Completed.

410-07877-870-97

DECARIE-RAIMBAULT COLLECTOR

(*b*) City of Montreal.
(*d*) Experimental and design.
(*e*) Study on a 1/24 scale model of the flow conditons in a major collector running occasionally under pressure; investigation of ways of suppressing water level rises causing flood conditions. Study of the set-up of various flow meters to ensure proper discharge measurement.
(*f*) Completed.

410-07878-340-73

TAILRACE TUNNEL-TEMISCAMING HYDRO-ELECTRIC POWER PROJECT

(*b*) Hydro-Qubec, Montreal.
(*d*) Experimental and design.
(*e*) Study on a 1/48 scale model of the head losses and surge waves in the tailrace manifold and in the 3,500 ft. tunnel designed to flow at free surface.
(*f*) Completed.

410-07879-300-70

LAND RECLAMATION IN THE ST. LAWRENCE RIVER

(*b*) Desourdy Construction Ltd., Montreal.
(*d*) Experimental and design.
(*e*) Study on an existing 1/150 vertical and 1/600 horizontal scale model of the St. Lawrence River in the reach of Laprairie Basin–Lanoraie. Determination of the influence of approximately 250 acres of back filling; effects on water levels and flow velocities in free water conditions; simulation of ice conditions with and without the back filling.
(*f*) Completed.

410-07880-300-97

LAND RECLAMATION IN THE ST. LAWRENCE RIVER

(*b*) City of Montreal.
(*d*) Experimental and design.
(*e*) Study to determine the influence of back filling in the vicinity of two islands; effect on water levels and flow velocities in free water conditions together with the formation of the ice cover during the winter period. Study carried on the St. Lawrence River scale model reproducing 41.5 mi. of river at scales of 1/50 vertically and 1/600 vertically.
(*f*) Completed.

410-07881-300-97

LAND RECLAMATION IN THE ST. LAWRENCE RIVER

(*b*) Montreal Urban Community.
(*d*) Experimental and design.
(*e*) Determination of the appropriate configuration to be given to 150 acres of back filling. Influence on water levels, flow velocities and formation of the ice cover studied on a 41.5 mi. reach of the river (model at scale 1/150 vertically and 1/600 horizontally). Study of a water treatment plant sewage outfall location and of the resulting dilution along the river.

410-07882-310-96

FLOOD CONTROL ON THE SAINT-ANNE RIVER

(*b*) Dept. of Natural Resources, Water Branch, Quebec.
(*d*) Experimental and design.
(*e*) Investigation of flood conditions resulting from ice jam during the winter period and occasionally under severe rain conditions which cause overflowing of the river. Solutions were investigated on a movable bed distorted scale model (1/72 vertical and 1/50 horizontal) to reduce flooding and limit damage to the neighbouring houses and cultivated lands.

LAVAL UNIVERSITY, Department of Mechanical Engineering, Quebec 10, P.Q., Canada. Dr. C. I. H. Nicholl, Department Head.

411-08099-740-00

HYDRAULIC ANALOGY

(*c*) Dr. E. A. Eichelbrenner.
(*d*) Experimental and theoretical; basic research.
(*e*) A deep-water hydraulic analog to the two-dimensional unsteady flow of a gas has been established.
(*g*) The method has been used to model unsteady compressible flow in two passages connected by a convergent section having straight walls. The height of the liquid surface in the analog has been determined by photogrammetry.
(*h*) **Computation of Two-Dimensional Unsteady Isentropic Gas Flow, Using a Hydraulic Analogy**, F. U. Minhas, *Doctoral Dissertation*, 1972.

UNIVERSITY OF MANITOBA, Department of Civil Engineering, Hydraulics Laboratory, Winnipeg 19, Manitoba, Canada. V. Galay, Associate Professor.

412-06619-300-00

ENGINEERING INTERFERENCE WITH RIVERS

(*d*) Laboratory and field research project; applied research for M.Sc. thesis.
(*e*) To quantitatively and qualitatively assess the effects of engineering interference, such as dams and diversions, upon the behaviour of a river channel. Field investigations have been completed on the Seine River Diversion and are presently being conducted on the Assiniboine River.
(*g*) Analysis of data from the Seine River Diversion indicated that degradation of the channel was due to an extremely steep channel slope. Studies to stabilize the channel are continuing.

(*h*) **Degradation of the Seine River Diversion Channel,** O. Caron, *M.Sc. Thesis*, 1970.
Degradation of the Seine River Diversion, Galay, Block and Caron, presented at *ASCE Hydraulics Speciality Conf.*, Minneapolis, Aug. 1970.

412-06937-410-00

LAKE WINNIPEG EROSION STUDIES

(*d*) Field and laboratory; applied research.
(*e*) Investigation into the extent of beach erosion along the east and west shorelines of Winnipeg Beach. Protective measures at Winnipeg Beach are now being investigated in a hydraulic model.
(*g*) Field investigations indicate a general southerly movement of sand. A correlation has been obtained between the rate of bluff erosion, and lake level.
(*h*) **Shoreline Processes on Lake Winnipeg,** W. M. Veldman, *M.Sc. Thesis*, 1969.
Longshore Transport in the South Basin of Lake Winnipeg, W. Cheng, *M.Sc. Thesis*, 1971.

412-08132-320-73

BEHAVIOUR OF DIVERSION CHANNELS IN NORTHERN MANITOBA

(*b*) Manitoba Hydro.
(*d*) Field and laboratory applied research.
(*e*) The study of flow depths in dredged channels under a variety of flow conditions.
(*g*) Study in initial stages at present.

McMASTER UNIVERSITY, Department of Chemical Engineering, Fluid Mechanics Group, Hamilton, Ontario, Canada. Dr. A. E. Hamielec, Professor.

413-06056-070-90

VISCOUS FLOW THROUGH PARTICLE ASSEMBLAGES

(*b*) National Research Council of Canada.
(*d*) Theoretical and experimental; basic research for Doctoral thesis.
(*e*) Project is aimed at developing computer solutions of the Navier-Stokes equations for transient, incompressible flow through particle assemblages (fluidized and packed beds and bubble swarms) at intermediate Reynolds numbers. New techniques are being developed to account for particle interaction. Experimental work involves the measurement of the surface pressure distribution on a test sphere in a packed bed.
(*g*) Numerical solutions have been obtained for flow through bubble swarms for Re = 0-1000 and porosity, 0.4-1.0.
(*h*) **Viscous Flow through Particle Assemblages at Intermediate Reynolds Numbers–Steady-State Solutions for Flow through Assemblages of Cylinders,** B. P. LeClair, A. E. Hamielec, *I&EC Fund.* **9**, 608, 1970.
A Cell Model for Transport in Bubble Swarms, *Can. J. Chem. Engrg.* **49**, 713, 1971.

413-06947-030-00

VISCOUS FLOW AROUND BLUNT BODIES—METEOROLOGICAL APPLICATIONS

(*c*) Dr. A. E. Hamielec, and Dr. H. R. Pruppacher, Assoc. Prof., Dept. of Meteorology, Cloud Physics Laboratory, Univ. of Calif., Los Angeles, Calif.
(*d*) Theoretical and experimental; basic research for Doctoral thesis.
(*e*) Measurement and prediction of transient and steady-state drag, internal circulation and evaporation of raindrops and collision efficiencies.
(*f*) New accurate measurements and predictions of the evaporation of spherical raindrops have been made.
(*h*) **A Numerical Study of the Drag on a Sphere at Low and Intermediate Reynolds Numbers,** B. P. LeClair, A. E. Hamielec, H. R. Pruppacher, *J. Atmos. Sci.* **27**, 308, 1970.
A Numerical Method of Determining the Rate of Evaporation of Small Water Drops Falling at Terminal Velocity in Air, S. E. Woo, A. E. Hamielec, *J. Atmos. Sci.* **28**, 1448, 1971.
A Wind Tunnel Investigation of the Rate of Evaporation of Small Water Drops Falling at Terminal Velocity in Air, K. V. Beard, H. R. Pruppacher, *J. Atmos. Sci.* **28**, 1455, 1971.
Circulation in Raindrops, B. P. LeClair, A. E. Hamielec, H. R. Pruppacher, *J. Atmos. Sci.*, in press.

413-06948-120-90

FLOW OF DILUTE POLYMER SOLUTIONS

(*b*) National Research Council of Canada.
(*d*) Theoretical and experimental; basic research for Doctoral thesis.
(*e*) Project is aimed at developing constitutive equations for flow of polymer melts with due regard to distribution of molecular weight, branching and chain degradation.
(*g*) A high shear couette viscometer of shear rate capability, 10^6 sec^{-1} has been built and evaluated. The shear degradation of polyacrylamide in water is presently being studied.

UNIVERSITÉ DE MONCTON, Department of Engineering, Moncton, N.B., Canada. Dr. J.-R. Longval, Department Head.

414-07883-860-90

THERMAL BUDGET OF RIVERS AND RESERVOIRS

(*b*) National Research Council of Canada, Dept. of Environment, Canada.
(*c*) Mr. Numa Marcotte, Assoc. Professor.
(*d*) Experimental and theoretical; applied research.
(*e*) Study of method of calculating water temperature at hourly intervals using meteorological and hydrological data; applications.
(*g*) Observations in an experimental canal led to improved method of calculation. Same basic method applied to rivers gives good agreement between calculated and measured water temperatures at daily intervals in Chaudire and Yamaska rivers.
(*h*) **Echanges Thermiques Air-Eau Analyse d'Observations Expérimentales,** N. Marcotte, *Proc. 14th Congr. IAHR* **1**, 349-56, 1971.
La Température de l'Eau des Riviéres: Quelques Résultats de Mesures et de Calculs, N. Marcotte, M. Q. Trinh, *39th Congr., ACFAS*, Oct. 1971.

NATIONAL RESEARCH COUNCIL, Division of Mechanical Engineering, Hydraulics Section, Montreal Road, Ottawa, K1A 0R6, Canada. J. Ploeg, Section Head.

415-06602-400-90

TIDAL HYDRAULIC MODEL OF THE ST. LAWRENCE RIVER AND ESTUARY

(*b*) Ministry of Transport.
(*c*) Mr. J. Ploeg, Dr. B. D. Pratte.
(*d*) Experimental, applied research.
(*e*) A hydraulic model of the tidal reach of the river has been constructed and calibrated for the study of navigation improvements.
(*h*) **Comprehensive Tidal Study of the St. Lawrence River,** J. Ploeg, J. W. Kamphuis, *Proc. 11th Conf. Coastal Engrg.*, London, 1968.

415-06603-400-90

MATHEMATICAL MODEL OF THE ST. LAWRENCE RIVER AND ESTUARY

(*b*) Ministry of Transport.
(*c*) Dr. D. Prandle.
(*d*) Theoretical; applied research.
(*e*) A combined one- and two-dimensional numerical model, using finite difference methods of calculating tidal propagation along the St. Lawrence River.
(*h*) **Comprehensive Tidal Study of the St. Lawrence River,** J. Ploeg, J. W. Kamphuis, *Proc. 11th Conf. Coastal Engrg.*, London, 1968.

415-07095-300-00

MATHEMATICAL MODEL OF THE LOWER FRASER RIVER

(*c*) Dr. D. Prandle, Mr. N. Crookshank.
(*d*) Theoretical; applied research.
(*e*) Finite difference explicit method of calculating tide propagation in the Lower Fraser River to determine navigation improvements.
(*h*) **One-Dimensional Mathematical Model of the Lower Fraser River,** N. Crookshank, *LTR-HY-14*, Mar. 1971.

415-07098-420-00

WAVE DIRECTION STUDY

(*c*) Mr. J. Ploeg.
(*d*) Field study; theoretical; basic research.
(*e*) Using a triangular array of wave sensors in deep water in Lake Ontario, Ontario, measurements are being made to determine the direction of propagation of wind generated waves and to calculate the actual wavelengths, corresponding to peaks in frequency spectrum.

415-08133-420-90

FORCES ON OFF-SHORE STRUCTURES

(*b*) Public Works–Canada.
(*c*) Dr. B. D. Pratte.
(*d*) Experimental, theoretical; applied research.
(*e*) Using a scale model of a deep water off-shore mooring point, wave forces sensed by strain gauges are recorded on-line with an EAI-640 computer. Regular and random waves are used.
(*h*) **Instrumentation to Measure Wave Forces on a Model Pile,** B. D. Pratte, *HY-80*, Apr. 1972.

415-08134-470-90

KINCARDINE HARBOUR MODEL STUDY

(*b*) Public Works–Canada.
(*c*) Dr. D. Prandle.
(*d*) Experimental; applied research.
(*e*) A scale model study of harbour resonance problems to investigate possible improvement schemes.
(*h*) **Model Study of Kincardine Harbour,** D. Prandle, *LTR-HY-23*, Mar. 1972.

415-08135-700-00

WAVE RECORDER DEVELOPMENT PROGRAM

(*c*) Mr. J. Ploeg, Mr. E. R. Funke.
(*d*) Experimental, theoretical; design, development.
(*e*) Two types of wave sensors have been developed, a staff gauge and a pressure cell. Both instruments have been tested extensively and are being used by various agencies.

415-08136-740-00

SPECTRAL ANALYSIS PROGRAM DEVELOPMENT

(*c*) Mr. E. R. Funke.
(*d*) Theoretical; applied research and development.
(*e*) Development of programs to analyze time series, either by F.F.T. methods or auto-correlation techniques. Typical applications are wave records and turbulent diffusion data. Programs can be used on-line.

415-08137-870-00

EXPERIMENTAL AND THEORETICAL STUDY ON DENSITY STRATIFIED FLOWS–OIL SLICK BEHAVIOUR

(*c*) Dr. D. Wilkinson.
(*d*) Experimental, theoretical; basic research.
(*e*) A study of the limitations of containment of oil slicks by floating booms. This shows that only for densimetric Froude numbers <0.5, oil can be contained by a boom.
(*h*) **Containment of Oil Slicks in the St. Lawrence River,** D. L. Wilkinson, *LTR-HY-16*, Dec. 1971.

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO, Hydraulic Model Laboratory, 620 University Avenue, Toronto 2, Ontario, Canada. Mr. J. B. Bryce, Hydraulic Studies Engineer.

416-06945-340-00

BRUCE GENERATING STATION

(*d*) Experimental; design.
(*e*) A 1:50 scale model of the complete condenser cooling water system from the intake in the bed of Lake Huron, the tunnel, tunnel exit, canal leading to the forebay, four pumphouses, discharge channel beneath power house, recirculating channel, to discharge into the lake. Model used to determine hydraulic design details and performance of all elements of system.
(*f*) Only submerged intake still under active investigation. Remainder of model removed.

416-06946-340-00

LENNOX GENERATING STATION

(*d*) Experimental, design.
(*e*) A 1:50 scale model of the features of the condenser cooling water system including intake in the bed of Lake Ontario, tunnel, tunnel exit, forebay, discharge structure, recirculating channel, energy dissipators in discharge channel, tempering water pumphouse on dyke and discharge channel for mixing behind the dyke offshore. All elements of the system were determined in detail and performance assured of this 2,200 MW oil-fired thermal station.
(*f*) Test program completed; model inactive.

416-07963-340-00

BRUCE GENERATING STATION, VACUUM BUILDING

(*b*) Atomic Energy Commission of Canada Limited.
(*c*) Mr. F. B. Schafheitlin, Design Superintendent, Auxiliary Processes, A.E.C.L. Sheridan Park, Ontario, Canada.
(*d*) Experimental; design.
(*e*) A 1:20 scale model of the vacuum building of a 4 × 750 MW nuclear power plant. Model simulates the spray-condensing system built into the vacuum building and is used to develop a design that would automatically release water from the storage tank into the spray pipes in response to the dynamic process triggered by an accidental release of nuclear steam.

416-07964-340-00

LENNOX GENERATING STATION

(*d*) Experimental, design.
(*e*) Several 1:12 air flow models of sections of the forced draft and induced draft ducting systems of a 2,200 MW fossil-fired thermal generating station. Models used to develop designs for specified gas distribution in critical cross-sections and to reduce headlosses.

416-07965-340-00

LENNOX GENERATING STATION

(*d*) Experimental, design.
(*e*) A 1:6 scale model of one cooling water intake well for a 550 MW block in a 2,200 MW fossil-fired thermal plant. Model used to determine well dimensions and shape in order to assure proper suction conditions for the cooling water pump.

416-07966-340-96

LORNEVILLE COOLING WATER INTAKE

(*b*) New Brunswick Electric Power Commission.
(*c*) Mr. C. W. Turner, Sr. Civil Engr., New Brunswick Elec. Power Comm., Fredericton, New Brunswick, Canada.
(*d*) Experimental; design.
(*e*) A 1:80 scale model of cooling water intakes and outfalls for a 2 × 300 MW fossil-fired thermal plant located at the Bay of Fundy. Model to be used to study the most suitable location and design of intakes to assure proper operating conditions for cooling water pumps with regard to wave action, silting and warm water circulation.
(*f*) Model under construction.

416-07967-350-96

JENPEG CONTROL STRUCTURE

(*b*) Manitoba Hydro.
(*c*) Mr. H. R. Hopper, Mgr., Hydraulic Engrg. Dept., Manitoba Hydro, P.O. Box 815, Winnipeg, Manitoba, Canada.
(*d*) Experimental, design and operation.
(*e*) A 1:80 scale model of a control weir and powerhouse on the Nelson River. Model to be used to study adequate design and location of water passages in control weir; the design and performance of energy dissipation works; rock stability during closure of the rock-fill cut-off dam.
(*f*) Model under construction.

416-07968-390-99

NIAGARA RIVER–AMERICAN FALLS MODEL

(*b*) American Falls International Board.
(*c*) Mr. B. Russell, P. Eng., Dist. Engr., Water Survey of Canada, Box 335, Guelph, Ontario, Canada.
(*d*) Experimental, for design.
(*e*) A 1:50 scale model of the American Falls at Niagara built for the American Falls International Board. Model is used by the Board to study schemes for the enhancement of the scenic appearance of the American cataract.
(*f*) Investigation completed; model still operational.

UNIVERSITY OF OTTAWA, Department of Civil Engineering, Hydraulics Laboratory, Ottawa, K1N 6N5, Canada. Dr. Ronald D. Townsend, Laboratory Director.

417-07998-360-00

HYDRAULIC JUMP DOWNSTREAM FROM A SLOT INFLOW

(*d*) Experimental; Master's thesis.
(*e*) In order to reduce the ecological impact of hot waste-water discharges it is a practice at some thermal power stations to mix tempering water with the waste-water in the discharge channel, thereby effecting a reduction in the temperature of the effluent before it discharges into the receiving body. The present research program is an investigation of the hydraulic jump as an efficient mixer of two different temperature streams.
(*g*) A model, utilising a 53 ft-long adjustable slope flume, has been constructed in the laboratory in which it is possible to produce a supercritical room temperature main stream with a subcritical, chilled lateral inflow entering the main stream at right angles. Turbulence intensities, Reynolds stresses and temperature distributions have been measured, downstream from the confluence of the two streams, and an attempt is being made to develop a method for locating the jump in the main channel under a comprehensive range of slot inflows.

417-07999-220-97

REDUCTION OF SCOUR AT INLET STRUCTURES TO FILTRATION TANKS

(*b*) City of Ottawa, Waterworks Engineering Department.
(*d*) Experimental; applied research for design; M.Eng. thesis.
(*e*) The problem of reducing the amount of scour that takes place in the vicinity of inlet control gates to the filtration tanks of an existing water purification plant facility is to be investigated using a hydraulic model. Flow diffusers, of different geometries, will be considered in combination with a more suitable filter surface material in an attempt to minimize the degree of scour at entry to the tanks.

417-08000-220-00

A LABORATORY INVESTIGATION INTO DESIGN CRITERIA FOR SUBMERGED PIPELINES CROSSING ALLUVIAL STREAMS

(*d*) Experimental; applied research; Master's thesis.
(*e*) The impending construction of large diameter natural gas and oil pipelines in the Yukon and Northwest Territories will involve the crossing of many streams. The major factor to consider in the design of northern stream crossings is the abnormally high rates of erosion of alluvial deposits associated with severe spring freshets. This project, which involved a laboratory model study, was initiated for the following reasons: (1) A need to obtain more realistic design criteria for submerged river crossings, (2) to provide a theory for estimating minimum depths of cover for a proposed crossing, and (3) to investigate means of improving the stability of the river bed material in the immediate vicinity of a crossing.
(*f*) Completed.
(*g*) The report points out how probability concepts may be used in selecting a safe depth of cover for a submerged pipeline crossing of a stream given a record of flood flows, or even better, a record of centreline bed profiles during flood flows. It was found that the concept of critical shear stress could be used in computing the required depth of cover, given the physical characteristics of the crossing, the flood discharge, and the grain size distribution curve for the bed material. Crushed rock placed immediately upstream and downstream from the pipe was found to enhance pipe stability during flood flows.
(*h*) **A Laboratory Investigation Into Design Criteria for Submerged Pipelines Crossing Alluvial Streams,** D. W. Farley, *M.Eng. Thesis*, Dept. of Civil Engrg., Univ. of Ottawa, Dec. 1971.
Design Criteria for Submerged Pipelines Crossing Alluvial Streams, D. R. Townsend, D. W. Farley. Submitted to the *Systems Symposium*, Purdue Univ., Oct. 1972.

417-08001-030-90

DIFFUSION IN THE WAKE OF AN OUTBOARD MOTOR BOAT

(*b*) National Research Council of Canada.
(*c*) Professor Richard G. Warnock.
(*d*) Experimental, basic research for Doctoral degree.
(*e*) Measurements of diffusion of fluorescin dye in the wake of a motor boat were made in a small pond. Purpose of the study was to learn about transport processes in such wake with a view to application to water quality control.
(*f*) Completed.
(*g*) Full-scale experiments were conducted in a pond by releasing a fluorescent dye into the wake of a boat to study the diffusion phenomenon. The dye was diffused in the wake by eddies of various sizes. Depth-averaged samples, collected from a platform at regular time intervals at

several points in a cross-section of the wake using specially designed samplers, were analyzed using fluorometric techniques. Several tests were conducted at a known boat-speed when the winds were calm. The cross-sectional distribution of concentration indicates that the lateral diffusion is much greater than the vertical diffusion. A mathematical model for the diffusion process in the wake is proposed, assuming similarity of concentration distribution profiles at various times in the cross-section. In this model, expressions have been derived for the variation of maximum concentration with time and for the lateral distribution of concentration at any time. Diffusion coefficients are computed using this model and also from the one-dimensional normal distribution equation. Tests conducted at different boat speeds seem to indicate that the diffusion is independent of the boat speed.

(*h*) **Diffusion in the Wake of an Outboard Motor Boat,** T. P. Halappa Gowda, R. G. Warnock, *AGU Ann. Mtg.*, 1972.
Diffusion in the Wake of an Outboard Motor Boat, T. P. Halappa Gowda, *Ph.D. Thesis*, Univ. of Ottawa. To obtain, write to correspondent.

417-08002-170-90

SIMILITUDE IN HEAT TRANSFER AT A WATER SURFACE IN A NONUNIFORM FLOW

(*b*) National Research Council of Canada.
(*c*) Professor R. G. Warnock.
(*d*) Experimental, basic research for Master's thesis.
(*e*) Purpose of the work is to determine relative importance of modeling parameters for heat transfer at a water surface in a nonuniform flow. It is hoped to apply the information to modeling of ice formation problems.

417-08003-300-96

DISPERSION IN THE MIXING ZONE OF TWO RIVERS

(*b*) Ontario Department of University Affairs.
(*c*) Professor R. G. Warnock.
(*d*) Field, basic research.
(*e*) Purpose of the work is to determine transport and dispersion of sediments and other materials in the mixing zone of a main stream and its tributary.
(*h*) **Channel Morphology and Dispersion Effects in Streams,** R. G. Warnock, presented at *Fluvial Processes, 3rd Ann. Colloquim of the Geog. Dept.*, Univ. of Ottawa, Mar. 1972.

QUEEN'S UNIVERSITY AT KINGSTON, Department of Civil Engineering, Hydraulic Laboratory, Kingston, Ontario, Canada. Dr. Arthur Brebner, Laboratory Head.

418-05674-690-90

STUDIES OF FLOW-THROUGH VORTICES

(*b*) The National Research Council of Canada.
(*c*) Dr. J. Boadway.
(*d*) Experimental and theoretical; Masters and Doctoral theses.
(*e*) Velocities, pressures and turbulence characteristics in a series of closed flow-through vortex chambers are being measured by photographic and electronic techniques.
(*f*) Completed.
(*h*) **An Investigation of Vortex Nozzles,** J. D. Boadway. Accepted for publication in *Canad. J. Chem. Engrg.*

418-06495-810-90

MAGNITUDE AND PROBABILITY OF PEAK FLOWS ON SMALL DRAINAGE BASINS IN SOUTHERN ONTARIO

(*b*) The National Research Council of Canada.
(*c*) Dr. W. E. Watt.
(*d*) Experimental and theoretical project; applied research for Masters and Doctoral theses.
(*e*) Determination of a technique for evaluating the peak discharge corresponding to a given return period and development of a simple, mathematical watershed model for small drainage basins.
(*h*) **A Relation Between Peak Discharge and Maximum Twenty-Four Hour Flow for Rainfall Floods,** W. E. Watt, *J. Hydrology* **14**, 285-292, 1971.

418-06497-000-90

THE CONTROL OF VELOCITY DISTRIBUTION IN A VORTEX

(*b*) The National Research Council of Canada.
(*c*) Dr. J. D. Boadway.
(*d*) Development of a device for clarifying fluids.
(*e*) The device is for clarifying fluid effluents by using the centrifugal forces in a forced vortex of high speed of rotation.
(*f*) Completed.
(*g*) A prototype of the device has been built and operated successfully. (Patents have been granted in some countries.)
(*h*) **Removal of Suspended Solids by Centrifugal Force,** J. D. Boadway. Accepted for publication in *Pulp and Paper Magazine of Canada.*

418-06498-860-96

WATER CLARIFICATION

(*b*) Dept. of Univ. Affairs, Province of Ontario.
(*c*) Dr. J. D. Boadway.
(*d*) Experimental and theoretical project; applied research for a Masters thesis.
(*e*) A study of sedimentation with centrifugal acceleration.
(*f*) Completed.
(*g*) An algorithm has been developed to simulate sedimentation in the presence of turbulence.
(*h*) A Masters thesis has been written on this work.

418-06980-220-90

DISTRIBUTION OF SEDIMENT CARRIED IN SUSPENSION

(*b*) National Research Council of Canada.
(*c*) Dr. M. S. Yalin.
(*d*) Theoretical and experimental; Ph.D. thesis.
(*e*) A theoretical and experimental investigation to determine the longitudinal variation of suspended sediment distribution when open channel flow passes from a smooth bed to a mobile bed of cohesionless material (or vice versa). The theoretical analysis rests on the convective diffusion equation; a laser-beam technique is used to measure suspended sediment concentration in a laboratory flume.

418-08100-870-00

THE EFFECT OF SEDIMENTATION WITH CENTRIFUGAL FORCE ON THE ACTIVATED SLUDGE PROCESS

(*c*) Dr. J. D. Boadway.
(*d*) Experimental project for a Masters thesis.
(*e*) A device which clarifies fluids using centrifugal force (see 06497) produces a dense sludge and has low retention time. The project is to investigate how much the activated sludge process will benefit from the production of a sludge which is fresher than normal.

418-08101-870-90

DISPERSION OF POLLUTANTS IN NATURAL STREAMS

(*b*) Canada-Department of the Environment.
(*c*) Dr. W. E. Watt.
(*d*) Experimental and theoretical project; applied research for Masters and Doctoral theses.
(*e*) A relation for the longitudinal dispersion of pollutants in natural streams is being developed.
(*h*) **On the Distribution of Sediment in a Two-Dimensional Flow Over a Mobile Bed,** M. S. Yalin, W. E. Watt, *Intl. Symp. on Stochastic Hydraulics*, Pittsburgh, pp. 365-378, 1971.

418-08102-370-90

BLOCKAGE, PLUG FLOW AND SLIDING BEDS IN PIPELINES TRANSPORTING SOLIDS

(*b*) National Research Council of Canada.
(*c*) Dr. K. C. Wilson.
(*d*) Experimental and theoretical project.
(*e*) This topic is directly associated with design problems which occur in pipelines used industrially for transporting solids. A mathematical model of the phenomena being investigated has been proposed. Experimental investigations will be combined with further analytical work on the model.
(*h*) **Slip Points of Beds in Solid-Liquid Pipeline Flow,** K. C. Wilson, *J. Hydraul. Div., ASCE* **96,** HY1, Proc. Paper 6992, pp. 1-12, Jan. 1970.
Parameters for Bed Slip Point in Two-Phase Flow, K. C. Wilson, *J. Hydraul. Div., ASCE* **97,** HY10, Proc. Paper 8426, pp. 1665-1679, Oct. 1971.
Design Implications of Bed Slip Model for Pipelines Transporting Solids, K. C. Wilson, *Symp. on Solids Transport in Slurries*, Amer. Inst. Chem. Engrg., Atlantic City, N.J., Aug. 1971.

418-08103-220-90

SEDIMENT TRANSPORT AT HIGH SHEAR STRESS

(*b*) National Research Council of Canada.
(*c*) Dr. K. C. Wilson.
(*d*) Experimental and theoretical project.
(*e*) A pressurized conduit system is used to obtain high shear stress at the surface of beds of deposited solids. The results extend the data from open channel experiments in which the shear stress is usually limited to lower values. The relative importance of bed-load motion and suspension of the bed material is studied.
(*h*) **Bed Load Transport at High Shear Stress,** K. C. Wilson, *Proc. ASCE* **92,** HY6, Nov. 1966.

418-08104-410-90

EQUILIBRIUM BEACH PROFILES

(*b*) National Research Council.
(*c*) Dr. J. W. Kamphuis.
(*d*) Basic experimental and theoretical research toward M.Sc. and Ph.D. degrees.
(*e*) Equilibrium beaches are formed by waves and compared to determine model scaling parameters.
(*h*) **Similarity of Equilibrium Beach Profiles,** M. J. Paul, J. W. Kamphuis, A. Brebner, presented at *Coastal Engrg. Conf.*, Vancouver.

418-08105-400-90

TIDAL INLETS

(*b*) National Research Council.
(*c*) Dr. J. W. Kamphuis.
(*d*) Basic experimental and theoretical research toward M.Sc. and Ph.D. degrees.
(*e*) A complex model study (tides, waves and currents) of a tidal inlet is performed to determine inlet stability and model scaling parameters.

418-08106-420-90

MASS TRANSPORT BY WAVES

(*b*) National Research Council.
(*c*) Dr. J. W. Kamphuis.
(*d*) Field research and model study toward M.Sc. degree.
(*e*) Underwater camera work and model study to relate mass transport to wave parameters.

418-08107-420-90

SHEAR STRESS IN WAVE BOUNDARY LAYER

(*b*) National Research Council.
(*c*) Dr. J. W. Kamphuis.
(*d*) Basic experimental and theoretical research toward M.Sc. and Ph.D. degrees.
(*e*) Shear stresses are measured directly in the boundary layer generated in an oscillating water tunnel.
(*h*) **Measurements of Bed Shear Stress Under Waves,** P. Riedel, J. W. Kamphuis, A. Brebner, presented at *Coastal Engrg. Conf.*, Vancouver.

418-08108-420-90

FORMATION OF RIPPLES UNDER WAVES

(*b*) National Research Council.
(*c*) Dr. J. W. Kamphuis.
(*d*) Basic experimental and theoretical research toward M.Sc. and Ph.D. degrees.
(*e*) Formation of bed form is measured in the wave flume and in the oscillating water tunnel and related to the wave parameters. These are related to selection of model scaling parameters.
(*h*) **Experiments on Ripple Formation Under Wave Action,** G. Mogridge, J. W. Kamphuis, presented at *Coastal Engrg. Conf.*, Vancouver.

418-08109-390-90

STATIC ICE FORCES

(*b*) National Research Council of Canada.
(*c*) Professor S. S. Lazier.
(*d*) Basic theoretical work and experimental work in the field; directed toward M.Sc. and Ph.D. degrees.
(*e*) Internal stresses with an ice sheet are measured in the field; examination of the role played by cracks in the ice sheet in ice zones is being carried out; properties of natural ice are examined by making this section in a cold room.
(*h*) **Temperature Gradient in a Lake Ice Cover,** Michel Metge, S. S. Lazier, *IAHR Ice Symp.*, Reykjavik, 1970.
Thermal Cracks in Lake Ice Sheets, Michel Metge, S. S. Lazier, presented at *IAHR Ice Symp.*, Leningrad, Sept. 1972.
Movements in Continuous Ice Sheets and Temperature Gradients in Ice Sheet, F. A. MacLachlan, S. S. Lazier, *Natl. Res. Council Canada Symp. on Snow and Ice*, Calgary, 1969.

UNIVERSITY OF SASKATCHEWAN, Department of Civil Engineering, Hydraulics Laboratory, Saskatoon, Saskatchewan, Canada. Professor C. D. Smith.

420-07093-360-90

HYDRAULIC JUMP IN SLOPING CIRCULAR PIPES

(*b*) National Research Council.
(*d*) M.Sc. thesis.
(*e*) Studies were made to check the application of the momentum equation to the hydraulic jump in a sloping circular pipe, in which the pipe flows full downstream from the jump. The variables considered include gate opening, head, slope, air flow, and tailwater depth.
(*f*) Completed.
(*g*) Air demand and air flow proved to be one of the most important factors affecting performance. A satisfactory check on the momentum equation was made, but since air entrainment phenomena cannot be scaled up, it was not possible to recommend a procedure for predicting prototype performance.
(*h*) **Hydraulic Jump in a Sloping Circular Conduit,** K. K. Sharma, *M.Sc. Thesis*, Univ. of Sask., Saskatoon, 1970.

420-07891-320-90

SIPHON INLET STRUCTURES

(*b*) National Research Council.
(*d*) M.Sc. thesis.

(*e*) Hydraulic model studies are being conducted on a simplified siphon inlet structure, involving a flow transition from a trapezoidal canal to a circular pipe, but without the use of warped walls.

UNIVERSITY OF SASKATCHEWAN, Department of Mechanical Engineering, Saskatoon, Canada S7N OWO. Dr. P. N. Nikiforuk, Department Head.

421-07892-210-00

UNSTEADY FLOW IN DUCTS

(*c*) D. H. Male, Assoc. Professor.
(*d*) Theoretical and experimental; M.Sc. thesis.
(*e*) This project is designed to provide information about the behaviour of unsteady gas flows in ducts similar to those encountered in cooling systems, various types of turbomachinery and natural gas pipelines. The basic objectives of the programme are to investigate the limitations of the quasi-steady flow analysis commonly used in this field and to determine the extent to which viscous effects influence the flow pattern.
(*h*) **Unsteady Flow in a Branched Duct,** B. E. L. Deckker, D. H. Male, *Proc. Inst. Mech. Engrs., London* **182,** 3H, pp. 104-113, 1967-68.
Fluid Dynamic Aspects of Unsteady Flow in Branched Ducts, B. E. L. Deckker, D. H. Male, *Proc. Inst. Mech. Engrs., London* **182,** 3H, pp. 167-174.
Behaviour of Rarefaction Waves at the Junction of a Branched Duct, D. H. Male, R. Chelsom, B. E. L. Deckker, *Proc. Inst. Mech. Engrs., London* **184,** 3G, pp. 11-16, 1969-70.

421-07893-700-00

DYNAMIC RESPONSE OF HOT-FILM ANEMOMETERS IN MERCURY FLOWS

(*c*) D. G. Malcolm, Assoc. Professor.
(*d*) Theoretical and experimental; Ph.D. thesis.
(*e*) The technique of constant-temperature anemometry has been applied with some success in liquid metals such as mercury and sodium for mean velocity measurements. It is the intention of this project to explore the dynamic response of constant-temperature, cylindrical hot-film sensors in mercury, with a view to establishing the limitations inherent in applying hot-film anemometry to turbulent flows of liquid metal. Preliminary results obtained using a digital computer indicate that the thick thermal boundary-layer, which is due to the extremely low Prandtl number of liquid metals, has a considerable attenuation effect at much lower fluctuation frequencies than is normally experienced in the case of fluids of moderate Prandtl number such as air. The computational schemes are being refined and experimental verification is planned.
(*h*) **Some Aspects of Turbulence Measurement in Liquid Mercury Using Cylindrical Quartz-Insulated Hot-Film Sensors,** D. G. Malcolm, *J. Fluid Mech.* **37,** 701-713, 1969.

421-07894-130-00

AIR ENTRAINMENT IN THE FUEL SPRAY MODEL CASE

(*c*) M. E. Stoneham, Assoc. Professor.
(*d*) Theoretical and experimental; basic research.
(*e*) A study of the mixing of air and highly atomised liquid jet is being undertaken to ascertain the interaction phenomena and the air entrainment characteristics. Subsequently it is intended to study the effects of air entrainment and mixing on combustion for the fuel spray model case.

421-07895-130-00

THE EFFECT OF SHOCK WAVE INTERACTION WITH AN ATOMISED LIQUID JET

(*c*) M. E. Stoneham, Assoc. Professor.
(*d*) Theoretical and experimental; M.Sc. thesis.
(*e*) The mechanism of interaction of a shock wave with an individual droplet and the interference between adjacent mono-size droplets during break-up is being studied. These investigations are considered a necessary preliminary and fundamental step towards the study of the interactive effects of shock waves and an atomised jet.

421-07896-600-00

DEVELOPMENT OF A FLUIDIC-HYDRAULIC VALVE

(*c*) J. N. Wilson, Assoc. Professor.
(*d*) Experimental; M.Sc. thesis.
(*e*) This project is concerned with the development of a new type of hydraulic valve using a fluidic vortex amplifier. This valve has a number of advantages over conventional spool valves because of the potential high reliability, because there are no moving mechanical parts, and potentially low cost because of the lack of high tolerance machining. To date, a valve having three or four way characteristics has been investigated and future plans are for an evaluation of this valve when connected to an actuator.

421-07897-600-00

INVESTIGATION OF AN AXI-SYMMETRIC FLUIDIC VALVE

(*c*) R. W. Besant, Assoc. Professor.
(*d*) Experimental; M.Sc. thesis.
(*e*) This project is concerned with an investigation of an axi-symmetric fluidic valve. This type of valve has potential application in a number of situations in which large flow rates of liquids must be switched in relatively short periods of time. The valve utilizes the Coanda effect for attachment to an axi-symmetric surface or wall. Work to date has been concentrated on identifying the various geometrical parameters which effect the static and dynamic performance of the valve.

SHERBROOKE UNIVERSITY, Department of Civil Engineering, Sherbrooke, Quebec, Canada. Dr. Bernard A. Gallez, Department Head.

422-07980-350-96

ICE PROBLEMS RELATED TO SPILLWAY'S OPERATION

(*b*) Ministère des Richesses Naturelles du Québec.
(*d*) Theoretical, experimental and field investigation; applied research and design.
(*e*) Study of the penetration of ice blocks into stilling basins. Protection of the floor, chute blocks and dentated sills.
(*g*) Computer simulation of trajectories completed. Experimental confirmation of theoretical results obtained. Some methods of protection, correction of existing spillways and rules of design proposed.
(*h*) **Trajectoire de corps flottants dans une veine fluide fortement dérivée,** M. Vandenbeusch, B. Gallez, *Paper B17, AIRH*, Paris 1971. Reports to Ministre des Richesses Naturelles, 1971-1972.

422-07981-700-80

THREE-DIMENSIONAL, STATIC AND DYNAMIC FORCE MEASURING DEVICE

(*d*) Theoretical and experimental investigation; development for Master degree.
(*e*) Development of a new six-component balance for hydrodynamic and aerodynamic research. Principle involved is pressure measurement in fluid bearings.
(*g*) Three prototypes completed. Calibration in progress.
(*h*) **Dynamométrie par coussins d'air,** M. Vandenbeusch, *M.S. Thesis*, Apr. 1970.
Balance hydrodynamique, conception, réalisation, étalonnage, *M.S. Thesis*, Dec. 1971.

422-07982-050-00

VERTICAL JET IN UNIFORM CURRENT–INSTABILITY AND CROSS WAVES

(*d*) Theoretical and experimental investigation; basic research for Master thesis.
(*e*) Investigation of the range of auto-oscillation of a jet from the bottom of a channel with uniform flow superimposed. Characteristics of the waves induced, generation of turbulence investigated with hot-film technique.
(*g*) Orientation tests give information on the relevant parameters. Identification of modes of oscillations completed.
(*h*) **Auto-oscillations d'un jet de fond sur courant uniforme,** B. A. Gallez. Rapport technique, available after July 1972.

422-07983-220-00

SEDIMENT TRANSPORT IN STREAMS HAVING SMALL AND HOMOGENEOUS WATERSHEDS

(*c*) Dr. C. Mitci.
(*d*) Field investigation; applied research.
(*e*) Establish relationships between flow, suspended sediment and washload; hydraulic geometry of streams.
(*g*) Preliminary analysis of field data shows that in small streams with homogeneous watersheds some relation could be established between the flow and the supended sediment load.

422-07984-220-00

BEDLOAD AND SEDIMENT TRANSPORT IN THE ST. LAWRENCE RIVER RELATED TO WATER INTAKE CHANNELS

(*c*) Dr. C. Mitci.
(*d*) Field investigation; design, operation.
(*e*) Applicability of existing bedload formulas to riverbeds with fine material.
(*g*) Field measurements in the water intake channel for the Gentilly Nuclear Station show that existing bedload equations do not give satisfactory results in the case of fine material.

422-07985-340-00

IDENTIFICATION, BY CORRELATION, OF HYDRO-ELECTRIC SYSTEMS

(*c*) Dr. Paul-Edouard Brunelle.
(*d*) Theoretical and field investigation; basic and applied research; basis for Master's thesis.
(*e*) Determination of system characteristics and transfer functions by correlation techniques so as to develop approximate models for optimal control of energy systems.
(*g*) Pseudo-random noise injection applicable to power systems. Recording and analysis instrumentation completed. Correlator interfaced to PDP-8. Software developed.
(*h*) **Identification d'un système par techniques de corrélation,** M. Tran Van, *Progress Report GCB-12-1*, December.

422-07986-860-90

WATER DISTRIBUTION NETWORK ANALYSIS AND OPTIMIZATION

(*b*) National Research Council of Canada.
(*c*) Dr. P. F. Lemieux.
(*d*) Theoretical and numerical approach. Applied research design and operation.
(*e*) Efficient computer programme for solving pipe network by time and memory saving. Program applied to minimize the cost of construction of pipe network.
(*h*) **Efficient Algorithm for Pipe Networks,** *Tech. Report PFL-2-72*, first part (to be published in Sept. 1972).

SIR GEORGE WILLIAMS UNIVERSITY, Department of Civil Engineering, Hydraulic Research Laboratory, Montreal 107, Canada. Dr. A. S. Ramamurthy, Associate Professor.

423-07898-240-90

EFFECT OF WALL CONSTRICTIONS ON FLOW INDUCED VIBRATIONS

(*b*) National Research Council.
(*d*) Experimental; applied research.
(*e*) Wake characteristics of flow past bluff bodies. The aim of the tests is to unify the geometric and fluid dynamic parameters that characterize the vortex shedding phenomena.

UNIVERSITY OF TORONTO, Department of Geography, Toronto 181, Canada. Professor A. V. Jopling.

424-07456-300-00

LABORATORY RIVER-DELTA SYSTEM

(*d*) Experimental; basic research in fluvial geomorphology.
(*e*) Small-scale experiments on the effects of sediment type on the pattern and geometry of stream and delta development; effects of base level change on the mode of aggradation and degradation in the system.
(*f*) Outdoor experimental facilities being established; some preliminary work done on three-dimensional deltas.

424-07457-390-00

MECHANICS OF MUDFLOWS

(*d*) Experimental and field; basic and applied research for Doctoral thesis in geomorphology.
(*e*) Factors affecting the movement of mudflows, including the transport of coarse debris; clastic fabrics produced by mudflows. The laboratory work has been integrated with field studies in the Canadian Rockies.
(*h*) Field and laboratory work completed.

UNIVERSITY OF TORONTO, Department of Mechanical Engineering, Toronto 5, Canada. Professor W. Douglas Baines, Department Chairman.

425-05627-640-00

BUILDING AERODYNAMICS

(*c*) Professor H. J. Leutheusser.
(*d*) Experimental; for design purposes.
(*e*) Determination of proximity effects on wind loading of highrise buildings; and related topics.
(*g*) Because of mutual sheltering, positive pressures are on the whole attenuated. Due to increased convective acceleration, negative pressures are universally enlarged, i.e., become more negative.
(*h*) **Static Wind Loading of Grouped Buildings,** H. J. Leutheusser, *Paper No. II.4*, *Proc. Intl. Conf. on Wind Effects on Buildings and Structures*, Tokyo, Japan, Sept. 1971.

425-06007-240-00

FLOW INDUCED VIBRATION OF BEAMS

(*c*) Professor W. D. Baines.
(*d*) Experimental, applied research for Doctoral dissertation.
(*e*) Vibration of a cylinder of equilateral cross-section caused by vortex trail studied in a wind tunnel. Pressure distribution around cylinder used to predict instantaneous forces.

(*g*) Found that vibration amplitudes very much smaller than for circular cylinders. Phase of pressure fluctuations on surface readily related to motion of vortices in wake. Critical region found at resonance of Strouhal frequency with frequency of support system. Lift force decreases below resonance and jumps to double value just above.
(*h*) **Measurements of Unsteady Pressure Distributions Due to Vortex Induced Vibration of a Cylinder of Triangular Section,** *IUTAM-IAHR Symp. on Flow-Induced Structural Vibrations*, Karlsruhe, Germany, 1972.
Vortex Induced Vibrations of an Equilateral Triangular Section, *Ph.D. Dissertation*, Univ. of Toronto, 1972.

425-06009-860-00

PROBABILISTIC MODELS OF STORAGE RESERVOIRS

(*c*) Professor V. Klemes.
(*d*) Theoretical; applied research.
(*f*) Completed.
(*h*) **On One Difference Between the Gould and Moran Storage Models,** V. Klemes, *Water Resour. Res.* **7,** 2, 1971.

425-06811-130-00

ENERGY LOSSES IN TWO-PHASE FLOW

(*c*) Professor L. E. Jones.
(*d*) Experimental and theoretical for Doctoral thesis.
(*e*) Concerns flow of flashing fluid in horizontal circular pipe, to gain insight into development of two-phase single-component flow by investigating pressure gradients, local void fractions and phase velocities. Hot-film anemometer has been direct-connected to computer for innovative data sampling at high frequency.
(*f*) Experimental study complete; thesis in preparation (R. Abel).

425-06817-360-00

TURBULENCE MEASUREMENTS IN WATER

(*c*) Professor H. J. Leutheusser.
(*d*) Experimental; basic research.
(*e*) Evaluation of turbulence parameters in hydraulic jump.
(*g*) Results, including intensity, Reynolds stresses, spectra, etc., have been obtained in two-phase flow roller region using novel digital evaluation technique. Findings confirm significant effect of condition of flow into jump.
(*h*) **Mesures de turbulence dans le ressault hydraulique,** F. J. Resch, H. J. Leutheusser, *La Houille Blanche*, No. 1, pp. 17-32, 1971.

425-07460-060-00

ENTRAINMENT BY A PLUME AT AN INTERFACE

(*c*) Professor W. E. Baines.
(*d*) Experimental and theoretical.
(*e*) A buoyant plume such as that from a chimney strikes a density interface perpendicularly. Entrainment through the turbulent zone of size about twice the diameter of the plume was measured by observing the change in depth of the second fluid.
(*f*) Completed.
(*g*) It was found that the velocity of entrainment was proportional to the cube of the densimetric Froude number. This is equivalent to a flux of buoyancy from one fluid into the other being proportional to the Froude number.
(*h*) **Entrainment from a Density Interface by a Plume or a Jet,** submitted to *J. of Fluid Mechanics*.

425-07461-240-00

AERODYNAMIC OSCILLATIONS OF BLUFF CYLINDERS

(*c*) Professor I. G. Currie.
(*d*) Theoretical and experimental.
(*e*) A basic study intended to better the understanding of the interaction between the fluid flow around an elastically supported body and the dynamic response of the body.

425-07465-860-00

STUDY OF WATER USAGE IN METROPOLITAN TORONTO

(*c*) Professor L. E. Jones.
(*d*) Analytical; applied research for Master's thesis.
(*e*) Daily pumpage data have been computer-plotted and correlated with climatological data and with relevant information on land use and occupancy.
(*g*) Innovative methods of data presentation have disclosed significant behaviour patterns which provide a valuable means of assessing past performance and of providing a rational basis for future operations.
(*h*) **A Study of the Factors Affecting Water Use in Metropolitan Toronto,** I. L. Guerra, *M.A.Sc. Thesis*, Univ. of Toronto, 1970.

425-07468-360-99

ENERGY DISSIPATORS FOR STREAM DIVERSIONS

(*b*) Consulting assignment.
(*c*) Professor L. E. Jones.
(*d*) Analytical and experimental; applied research.
(*e*) Urban development requires relocation of natural streams and significant energy dissipation.
(*g*) An innovative design ("multistage weir-pool-orifice energy dissipator") has been developed and model-tested to show substantial advantages and economies. The two units so far constructed have capacities of 10,000 and 14,000 HP, respectively, and the model studies show a capabiltity of up to 100 percent overload.

425-07472-810-00

MATHEMATICAL MODELS OF RAINFALL-RUNOFF RELATIONS

(*c*) Professor V. Klemes.
(*d*) Theoretical; basic research.
(*f*) Completed.
(*g*) Several types of conditions have been identified under which the probability distribution of runoff is negatively skewed.
(*h*) **Negatively Skewed Distribution of Runoff,** V. Klemes, *IASH Symp. of Wellington (N.S.)*, *Publ. No. 96*, IASH-Unesco, 1970.
Some Problems in Pure and Applied Stochastic Hydrology, V. Klemes, *Symp. on Statistical Hydrology*, Univ. of Arizona, Tucson, 1971.

425-07474-210-00

ZERO-FLOW WATERHAMMER

(*c*) Professor H. J. Leutheusser.
(*d*) Analytical and experimental; basic research for Doctoral thesis.
(*e*) Mechanics of pulse transmission in viscous fluid lines.
(*g*) Parallel-flow theory with closed-form solution for arbitrary velocity input has been developed.
(*h*) **Zero-flow Waterhammer,** D. A. P. Jayasinghe, H. J. Leutheusser, *Proc. Symp. Intl. Assoc. for Hydraulic Research*, Paper No. E2, Stockholm, Sweden, Aug. 1970.
Pulsatile Waterhammer Subject to Laminar Friction, D. A. P. Jayasinghe, H. J. Leutheusser, *J. Basic Engrg., Trans. ASME*, Paper No. 71-WA/FE-11.

425-07899-010-00

BOUNDARY LAYER SEPARATION ON BLUFF BODIES

(*c*) Professor I. G. Currie.
(*d*) Experimental and theoretical; basic research for Doctoral thesis.
(*e*) The nature of flow in the vicinity of a separation point on a bluff body is under investigation with a view to bettering our understanding of the separation phenomenon.
(*g*) By employing a potential flow model for a circular cylinder it has been possible to calculate the location of

the separation point and to verify the results by experiments.
(*h*) Doctoral thesis in preparation.

425-07900-200-00

FREE SURFACE FLOW OVER FINITE OBSTACLES

(*c*) Professor I. G. Currie.
(*d*) Experimental and theoretical; basic research for Doctoral thesis.
(*e*) A boundary weighted residual analysis is being applied to the free surface flow over an obstacle on the bottom.
(*g*) Results of the analysis show good agreement with experimental observations with respect to free-surface profiles, etc.
(*h*) Doctoral thesis is in preparation.

425-07901-200-99

HYPERBOLIC CURVES FOR OPEN-CHANNEL BENDS

(*b*) Consulting assignment.
(*c*) Professor L. E. Jones.
(*d*) Analytical and experimental; applied research.
(*e*) Model studies of channels with extreme curvature.
(*g*) Because of its favourable radius-of-curvature characteristics, the hyperbola shows great promise for use where extremes must be accommodated in open-channel bends (wide channel and short radius). Model studies indicate that substantial economies are possible in land requirement and construction cost.

425-07902-440-00

DE-EUTROPHICATION OF SMALL LAKES

(*b*) Collaborative with Dept. of Zoology.
(*c*) Professor L. E. Jones.
(*d*) Analytical; field investigation.
(*e*) Analysis for a given lake indicates that boat-borne pump of moderate capacity can effect a thermal de-stratification with reasonable time. The resulting instability should then permit a more efficient involvement of the natural agencies of sun and wind.
(*f*) Fieldwork to be undertaken during the summer of 1972.

425-07903-020-00

INTERMITTENCY IN TURBULENT FLOWS

(*c*) Professor J. F. Keffer.
(*d*) Experimental.
(*e*) Continuing investigation of the properties of the turbulent/non-turbulent interface at the free edge of shear flows, e.g., boundary layers, wakes and jets, using on-line digital sampling techniques.

425-07904-480-00

WIND STRUCTURE OVER URBAN AREAS

(*c*) Professor J. F. Keffer.
(*d*) Field study.
(*e*) Examination of the turbulent properties of wind when distributed by large buildings in an urban environment.

425-07905-050-00

SWIRLING JETS

(*c*) Professor J. F. Keffer.
(*d*) Experimental and theoretical.
(*e*) Analysis of turbulent characteristics of single and double swirling jet flows to study entrainment properties of the motion.
(*f*) Completed.

425-07906-030-00

ASYMMETRIC FLOWS

(*c*) Professor J. F. Keffer.
(*d*) Experimental.
(*e*) Determination of mixing characteristics of a wake generated by a pair of unequal cylinders.
(*f*) Completed.

425-07907-810-00

OPTIMUM RUNOFF FORECAST FOR FLOW CONTROL RESERVOIRS

(*c*) Professor V. Klemes.
(*d*) Theoretical; applied research.
(*e*) Extent to which reservoir performance can be improved by runoff forecast is studied.
(*g*) Preliminary results indicate that for a given type of regulation and given reservoir storages there exists an optimum length of the forecast period.

UNIVERSITY OF TORONTO, Institute of Environmental Sciences and Engineering, Toronto 181, Canada. Professor P. H. Jones, Chairman.

426-07458-440-00

THERMAL STRUCTURE, HEAT STORAGE AND EVAPORATION FOR LAKE ONTARIO

(*c*) Professor G. K. Rodgers.
(*d*) Field study in basic research.
(*e*) The study is presently directed toward study of the thermal bar–the development of thermal structure in a large lake; toward study of the thermal fine structure in the deep parts of the lake; and toward the estimate of evaporation through the heat budget techniques.
(*g*) Results include a description of the extent of fine structure in Lake Ontario, and a prediction scheme for the period of partial thermal stratification in spring.

UNIVERSITY OF WATERLOO, Department of Chemical Engineering, Waterloo, Ontario, Canada. Dr. K. F. O'Driscoll, Department Chairman.

427-06953-020-90

LIQUID MIXING IN AGITATED VESSELS

(*b*) National Research Council of Canada.
(*c*) Professor M. Moo-Young.
(*d*) Experimental research.
(*e*) The quality of liquid mixing in mechanically-agitated tanks and bubble columns is being examined in terms of energy consumption and systems variables to yield design criteria for chemical and fermentation reactors.
(*g*) Results available in publications.
(*h*) **Non-Ideal Flow Parameters for Viscous Fluids,** Moo-Young and Chan, *Can. J. Chem. Eng.* **49,** 187, 1971.
Blending Efficiencies of Impellers, Moo-Young, Tichar and Dullien, *J., AIChE* **18,** 178, 1972.

427-06954-150-90

FLUID FLOW AND MASS-TRANSFER

(*b*) Dept. of the Environment, Canada.
(*c*) Professor M. Moo-Young.
(*d*) Theoretical and experimental research.
(*e*) The physical and mass-transfer properties of exposed channels and bubble swarms are being studied for use in the design of flotation cells and aerobic waste treatment facilities.
(*g*) Interim results reported in publications below.
(*h*) **Generalized Expressions for Gas Absorption Rates in Bubbles,** Hirose, Moo-Young, *Chem. Eng. Sci.* **25,** 729, 1970.
Bubble Motion Studies in a Counter-Current Flow Apparatus, Moo-Young, Fulford and Cheyne, *I.E.C. Fund.* **10,** 157, 1971.
Hydrocarbon Fermentations, Moo-Young, Shimizu and Whitworth, *Biotechnol. Bioeng.* **8,** 1971.

WESTERN CANADA HYDRAULIC LABORATORIES LTD., 1186 Pipeline Road, Port Coquitlam, B.C., Canada. Mr. Duncan Hay, Director.

428-06964-390-99

CAPACITY AND HEAD LOSSES FOR FIRE HYDRANTS

(*b*) Terminal City Iron Works, Vancouver, B.C.
(*d*) Experimental for design and operation.
(*e*) Significant improvements in hydrant design resulted in improved capacity and lower head losses for a newly developed fire hydrant design. The improvements resulted from a previous test program carried out to determine the capacity of various fire hydrants, and to evaluate the head losses for their major component parts known as the boot and barrel.
(*f*) Completed.

428-06966-350-99

HYDRAULIC MODEL STUDIES OF THE SIRIKIT DAM SPILLWAY

(*b*) Engineering Consultants Incorporated for Ministry of National Development, Kingdom of Thailand.
(*d*) Experimental for design and operation.
(*e*) Studies are being carried out on a 1:36 scale model to evaluate the hydraulic characteristics of all components of the spillway tunnels, including aeration requirements and vibration potential at critical locations in the tunnel, mean and transient pressures at selected locations, and capacity curves for free and gate controlled flows.
(*f*) Completed.

428-06967-350-96

MODEL STUDIES OF WAVE ACTION INDUCED BY SLIDES INTO MICA DAM RESERVOIR

(*b*) Caseco Consultants for British Columbia Hydro and Power Authority.
(*d*) Experimental for design and operation.
(*e*) Extensive studies of the nature and magnitude of waves generated by landslides into a dam reservoir were conducted on a large outdoor 1:300 scale model of the reservoir formed by the 600-foot high Mica Dam presently under construction on the Columbia River in British Columbia. A section of Mica Dam was reproduced to a scale of 1:64 and data acquired from tests conducted on the 1:300 scale model of the reservoir were used as a basis for studies of the effects of waves on the dam.
(*f*) Completed.

428-07908-470-90

HYDRAULIC MODEL STUDIES, HARBOUR PROTECTION AND FORESHORE EROSION, OAK BAY, VANCOUVER ISLAND, BRITISH COLUMBIA

(*b*) Dept. of Public Works.
(*d*) Experimental for design and operation.
(*e*) The model studies were conducted in two phases to: (1) Provide data which would assist the Dept. of Public Works in establishing the optimum breakwater arrangement at the southern approach to Oak Bay Harbour. Additional protection is necessary for the existing small boat marina especially if existing facilities are expanded. (2) Examine the influence of the existing breakwater on the reported erosion of the foreshore at specified locations, and determine the effect on these areas of providing additional harbour protection, with a view to minimizing any undesirable conditions.
(*f*) Completed.

428-07909-410-90

HYDRAULIC MODEL STUDIES, BEACH STABILITY, PACIFIC ENVIRONMENT INSTITUTE, SANDY COVE, WEST VANCOUVER, BRITISH COLUMBIA

(*b*) Dept. of Public Works, Pacific Region, Vancouver, B.C.
(*d*) Experimental for design and operation.
(*e*) The model studies were conducted to examine the movement and deposition of beach materials under the action of prevailing wave conditions with all proposed foreshore structures in place. Examine beach conditions west of the Pacific Environment Institute under the action of incident southeast waves and waves reflected from the proposed vertical-wall breakwater. For the interim foreshore development when the marginal wharf will be in place without the verical-wall breakwater, examine the movement and deposition of beach materials under prevailing wave conditions. If necessary, test remedial measures to reduce erosion of beaches adjacent to the site. Observe foundation conditions of the proposed vertical-wall breakwater.
(*f*) Completed.

428-07910-350-99

HYDRAULIC MODEL STUDIES, TAILRACE AREA–BRITISH COLUMBIA HYDRO AND POWER AUTHORITY, COLUMBIA RIVER DEVELOPMENT MICA PROJECT

(*b*) Intl. Power and Engrg. Consultants, Ltd., Vancouver, B.C.
(*d*) Experimental for design and operation.
(*e*) Studies were undertaken to assess conditions in the tailrace area during Mica powerplant, high-level outlet works, and spillway discharges. Conditions of interest were erosion and deposition of bed material adjacent to the tailrace tunnel portals, flow velocities, water levels, wave heights, and cofferdam arrangements.
(*f*) Completed.

428-07911-470-90

HYDRAULIC MODEL STUDIES, HARBOUR PROTECTION, CAPTAINS COVE (DEAS SLOUGH) MARINA, BRITISH COLUMBIA

(*b*) Dept. of Public Works, Pacific Region, Vancouver, B.C.
(*d*) Experimental for design and operation.
(*e*) Studies were conducted to determine the most suitable length, location, and type of breakwater required to afford wave protection for small craft and facilities moored in Captains Cove Marina.
(*f*) Completed.

428-07912-470-90

CHEMAINUS HARBOUR STUDIES

(*b*) Dept. of Public Works, Vancouver, B.C.
(*d*) Experimental for design and operation.
(*e*) Collecting and compiling wind and wave data. Reducing this data to a format suitable for analysis in studies for a breakwater.

428-07913-470-99

ROYAL VICTORIA YACHT CLUB

(*b*) H. M. R. Murray, Consulting Engr., Victoria, B.C.
(*d*) Experimental for design and operation.
(*e*) Consultations and study made for a breakwater.
(*f*) Completed.

428-07914-490-96

MICA RESERVOIR SLOPE STABILITY COMPARATIVE EROSION TESTS

(*b*) CASECO Consultants Ltd., for B.C. Hydro and Power Authority.
(*d*) Experimental for design and operation.
(*e*) Erosion tests were conducted on prototype glacial till, with velocities up to 38 fps, and compared with the erosion of model material through the use of a 1:8 scale geometrically similar test facility.

428-07915-410-90

HYDRAULIC MODEL STUDIES, ALTERNATIVES TO WESTERLY FILL, PACIFIC ENVIRONMENT INSTITUTE, WEST VANCOUVER, BRITISH COLUMBIA

(*b*) Dept. of Public Works, Pacific Region, Vancouver, B.C.
(*d*) Experimental for design and operation.
(*e*) The purpose of this study was to examine the feasibility of alternatives to the existing fill area at the westerly boundary of the Pacific Environment Institute, W. Vancouver, B.C.
(*f*) Completed.

THE UNIVERSITY OF WESTERN ONTARIO, Department of Applied Mathematics, Faculty of Science, London 72, Ontario, Canada. Professor J. H. Blackwell, Department Head.

430-07995-030-00

TIME DEPENDENT VISCOUS FLUID FLOW

(*c*) Professor S. C. R. Dennis.
(*d*) Theoretical.
(*e*) Properties of the initial flow of a viscous fluid past an impulsively started sphere, circular and elliptic cylinder have been calculated by obtaining semi-analytic time series solutions to the Navier-Stokes equations. The solutions obtained are valid for high Reynolds numbers and moderate values of the time. In addition to the time series solutions obtained, fully numerical computer solutions of the equations of motion have been obtained to large times for the case of a circular cylinder.
(*h*) **The Initial Flow Past an Impulsively Started Sphere at High Reynolds Number,** S. C. R. Dennis, J. D. A. Walker, *J. Engrg. Math.* **5,** 4, Oct. 1971.

430-07996-020-00

DISPERSION IN TURBULENT SHEAR-FLOW

(*c*) Dr. P. J. Sullivan.
(*d*) Theoretical and experimental.
(*e*) An analysis of experimental data on the motion of small spheres within turbulent shear flow using a Lagrangian frame of reference is carried out. The purpose is to test previously derived theory and to gather basic information that is germane to the dispersion mechanism of this type of flow. A numerical simulation, using a Markovian type model, has been successfully used to describe dispersion of a passive scalar in two-dimensional shear flows. With the Lagrangian data this simulation will be modified and extended to include more general flow situations.
(*h*) **Some Data On the Distance-Neighbour Function for Relative Diffusion,** P. J. Sullivan, *J. Fluid Mech.* **47,** p. 601, 1971.
Dispersion in a Two-Dimensional Shear Flow, *J. Fluid Mech.* **49,** p. 551, 1971.

430-07997-010-00

THREE-DIMENSIONAL BOUNDARY LAYER THEORY

(*c*) Dr. M. Zamir.
(*d*) Theoretical.
(*e*) The work is aimed at a reconstruction of boundary layer theory so as to accommodate three-dimensional boundary layers within its scope. The main feature of the approach is the use of tensor analysis to rederive the boundary layer equations in a form which is independent of the coordinate system. Three-dimensional boundary layers are of utmost importance since they arise in a wide variety of practical situations such as the flow in rivers and channels of non-circular cross-section.
(*h*) **Boundary Layer Theory and the Flow in a Streamwise Corner,** *Aero. J., Royal Aero. Soc.* **74,** 712, 1970.
Experimental Investigation of the Boundary Layer in a Streamwise Corner, *Aero. Quar.* **XXI,** 4, 1970.

UNIVERSITY OF WINDSOR, Department of Mechanical Engineering, Windsor, Ontario, Canada. Dr. T. W. McDonald, Chairman, Graduate Studies, Dept. of Mechanical Engineering.

431-06955-050-90

THREE-DIMENSIONAL CURVED WALL JETS

(*b*) National Research Council of Canada.
(*c*) Dr. K. Sridhar.
(*d*) Basic experimental research for M.A.Sc.
(*e*) Aim is to study three-dimensional effects on jet growth and separation.
(*f*) Completed.
(*h*) **Three-Dimensional Curved Wall Jets,** U. M. Patankar, K. Sridhar, *Paper No. 71-WA/FE 2, Winter Ann. Mtg., ASME,* Nov. 1971. To be published in *Trans. ASME, J. Basic Engrg.*

431-06956-210-90

DEVELOPING FLOW IN AN ANNULUS

(*b*) National Research Council of Canada.
(*c*) Dr. K. Sridhar.
(*d*) Experimental, theoretical, basic research for M.A.Sc. and Ph.D.
(*e*) Aim is to investigate the annular flow development for different Reynolds numbers, entrance geometry and turbulence conditions, and diameter ratios.
(*h*) **The Location of the Plane of Zero Shear in an Annular Flow,** A. A. Nicol, C. M. Ivey, K. Sridhar. Presented at *Third Can. Cong. Appl. Mech.,* May 1971.

431-06958-600-90

FLUIDIC AMPLIFIERS

(*b*) National Research Council of Canada.
(*c*) Professor W. G. Colborne, H. J. Tucker, K. Sridhar.
(*d*) Experimental, basic research for M.A.Sc. and Ph.D.
(*e*) Aim is to study the switching time for bistable and for turbulence amplifiers. The mechanism of switching in a bistable amplifier is also being studied by investigating the characteristics of the separation bubble. By developing an accurate model it is hoped that accurate predictions of switching time can be made for a variety of configurations and flows.
(*h*) **An Experimental Investigation of the Switching of a Bistable Fluidic Amplifier,** C. J. Williams, *M.A.Sc. Thesis,* Univ. of Windsor, 1970.
Experimental Study of Switching in a Bistable Fluid Amplifier, W. G. Colborne, C. J. Williams, *ASME Paper 72-FE-11.*

431-07916-210-90

ANNULAR DIFFUSERS WITH SWIRL

(*b*) National Research Council and Defence Research Board.
(*c*) Dr. K. Sridhar.
(*d*) Basic and applied research for M.A.Sc.
(*e*) Aim is to investigate effects of both inlet swirl and boundary layer on the performance of a number of equiangular divergent annular diffusers.
(*h*) **Effects of Inlet Swirl on Annular Diffuser Performance,** J. H. Schneider, K. Sridhar. Presented at *Third Can. Cong. Appl. Mech.,* May 1971. (Also *M.A.Sc. Thesis,* J. H. Scheider, 1971).

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

Current and recently concluded research projects in hydraulics and hydrodynamics for the years 1971-1972 are summarized. Projects from more than 250 university, industrial, state and federal government laboratories in the United States and Canada are reported.

17. KEY WORDS (Alphabetical order, separated by semicolons)
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